THE ENGINEER

A Seven-Day Journal

The Guest Memorial Hall and Dowlais Works

THE reopening of the Guest Memorial Hall, after extensive reconditioning by the Guest Keen Baldwins Iron and Steel Company, Ltd., took place on Monday last, and this ceremony recalls an interesting piece of British industrial history. The hall was built as the result of the desire of workmen to provide a memorial to Sir Josiah Guest, who died in 1852, and their subscriptions were supplemented by financial help on the part of the company. The Dowlais works were situated on the site of some of the earliest beginnings of the British iron and steel industry and date back to 1759, when Mr. Thomas Lewis started the "Merthyr Furnace" with a partnership of nine persons and a capital of £4000. John Guest went to Dowlais in 1760 and was succeeded as manager by his son Thomas in 1780. At this time iron was taken to the seaports by pack mule, but later a canal was built, and it was in 1804 that Richard Trevithick built his first locomotive and the adjoining Penydarren works was connected to the canal 9 miles away. In succeeding years large quantities of iron rails were supplied for the construction of the Great Western Railway and regular shipments were being made to the Continent and America. The works then were largely owned by Sir Josiah John Guest and Mr. Wyndham Lewis, both descendants of original members of the firm. In 1854 the first steel rail made by the Bessemer process at Dowlais was rolled at the company's works, and in the first half of the century it was probably one of the largest works in the country, employing some 10,000 hands. As time passed local ore deposits were worked out, and when by the latter half of the nineteenth century ore had to be imported and brought to the works by rail, technical superiority was being offset by need for uneconomic haulage of ore and finished products. Eventually in 1935 the main operations were moved to a new integrated iron and steel works at Cardiff. The foundry, which had always been carried on as an ancillary to the main production at Dowlais, was left behind and is now undergoing extensive reorganisation and re-equipment.

British Cast Iron Research Association

MEMBERS and other interested parties were able once again to visit the Alvechurch laboratories of the British Cast Iron Research Association during its Open Days on July 2nd and 3rd. During the last two years much progress has been made in the process of removing laboratory and experimental work from the original building of Bordesley Hall to premises external to the Hall, leaving the Hall almost entirely for administration purposes. The Association is very actively engaged on both long-term and short-term research work. A very important aspect of its work is naturally concerned with the further development of nodular graphite cast iron. There is also much modern equipment elsewhere for the several analytical techniques it is pursuing. Notable amongst these items is the high vacuum induction crucible for determining oxygen, hydrogen and nitrogen contents of cast iron which amounts to about 2 millilitres per 20 grammes. An outstanding piece of equipment in its range of spectrographic instruments is the quantometer, which has only very recently been installed. The quantometer comprises a high-precision source unit which can reproduce a considerable variety of electrical discharges; a spectrometer which measures spectra by means of photo-electric cells, and a recording console which records through an electronic integrating system the photocell currents produced in the spectrometer. The instrument was first applied for at a time when the United Kingdom was receiving Marshall Aid. It is anticipated that the ordinary elements in a cast iron usually determined spectrographically will be recorded within sixty seconds of the sparking of the sample, and it is hoped also to be able to carry out determinations of carbon and phosphorus, elements which are not normally capable of being determined by spectrographic means. Other investigations which have been carried out on foundry atmospheres generally have led to a much improved dust extraction system on stand grinders.

Alkali Works Report, 1951

THE eighty-eighth annual report of the Chief Alkali Inspector of the Ministry of Housing and Local Government and of the Chief Inspector for Scotland, covering the year 1951 has been published this week. It states that the number of works registered was 1042, involving 1884 separate processes, and that many small works had closed down and the processes had been transferred to larger works. Registered works are increasing in size and tending to be located in the less populated districts, so that more travelling time is involved and due to the time spent visiting unregistered works it was not possible to pay the same number of visits to each registered works as in pre-war days. The number of infractions and the process involved is recorded, and in all cases of near infractions the conditions have been corrected without need for legal proceedings. Two new regional smoke abatement committees have been formed. The conditions obtaining at a number of spoilbanks are reported upon and there are notes upon visits to unregistered processes such as electricity generating stations, steam-raising plants, coke ovens, industrial furnaces, gasworks, and a wide variety of other plants, mainly to investigate complaints and to suggest remedies. The report discusses the registered works and cement production has continued to provide problems; that of cement dust is far from being solved, but improvement in low-level emissions continues. Carbon black production, it is stated, has caused atmospheric pollution problems, and it is proposed to burn the tail gases under boilers to render the gases inoffensive. The Chief Inspector gives some details of the fume emission troubles at the refineries and the precautions taken. Appendices give tabular statements of visits and processes, and state that 1,579,000 tons of sulphuric acid were produced in Great Britain during the year, mostly in contact plants, while the total tar distilled amounted to 2,699,470 tons. The report is published by H.M. Stationery Office and costs 2s.

Productivity in Steel Construction

THE fifty-third productivity team to be sent from Britain to the United States has now published its report. The team's objective was to study American factory layouts, methods and techniques, working conditions and management in vogue in constructional steelwork of three categories, namely, bridgework and structural steelwork, steel platework, and mechanical handling plant. The report seeks to describe the main differences and similarities in methods and conditions as observed during the team's visits. Basically, it is stated, the shop layouts seen were similar to those in Britain, but they were more often laid out to facilitate the regular flow of materials and had many labour-saving arrangements to ensure quick handling. These arrangements included the extensive use of subsidiary lifting and moving devices, fork trucks and mobile tractors. In the despatch of finished plant a great advantage in America is that much larger units can be despatched by rail then is practicable by rail or road in Britain, a procedure giving considerable economies over assembly on site. Higher rates of output per man are achieved in the U.S. in bridge and structural work. An important contribution to this condition, the report states, is the extensive use of wide-flanged beams. Another reason for greater productivity in America is given as the absence of trade demarcation and restrictive practices in the shops. In platework—as in bridgework and structural steelwork—work on details is carried much further in the drawing-office, a method which simplifies production later in the workshop. Because of the adoption of differing safety factors in the welding of joints, British works have to use steel plates thicker than are otherwise required. It is suggested that the British efficiency factor should be reviewed so as to economise in the use of plate. The study of mechanical handling is included in the curricula of many American colleges and universities. As a general conclusion, the report states that the breakdown of skills and operations common in mechanised industries cannot be used to any great extent in the industries which were visited, and efficient working must be gained by good layout, time study and the economical and flexible use of labour.

Water Supply at Glasgow

GLASGOW Corporation, at its meeting on June 26th, approved the route for a proposed tunnel under the River Clyde for the water department's 36in. diameter west main, which is now under construction. The tunnel will be of 12ft. internal diameter and lined throughout with cast iron segments, most of the work being carried out under compressed air. Airlocks will be provided at each of the two shafts, 18ft in diameter, which will be approximately 110ft in depth and will also be lined with cast iron segments. The tunnel will be about 340 yards in length and the crown will be some 40ft below the bed of the River Clyde. The total estimated cost of the project is £380,000. The Corporation will now seek an Order under the Water (Scotland) Act, 1946, from the Secretary of State for Scotland, and construction will commence, it is stated, immediately this Order is approved. The tunnel results from the fact that the proposed Whiteinch/Linthouse vehicular tunnel, for which the Corporation has been endeavouring to secure approval for several years, is not likely to receive ministerial approval yet. It was originally planned that the west main should pass through the vehicular tunnel, but owing to the urgent need for improving supplies to the southern and western parts of the city, the Corporation decided to proceed with a separate water main tunnel. The west main is already under construction from the service reservoirs at Milngavie to the Forth and Clyde Canal at Cloberhill, a distance of some 4¼ miles. With the fixing of the position at which the main will cross the River Clyde it is now possible to continue with the construction of the remaining 5 miles of 36in diameter main. The total estimated cost of the west main is £992,000, including the tunnel, for which the consulting engineers, Messrs. Mott, Hay and Anderson, will be responsible. The west main works will be carried out by the water department staff under Mr. Stanley D. Canvin, chief engineer and general manager.

Tacoma Narrows Bridge

No. I

In an article which appeared in THE ENGINEER *of March* 2, 1951, *details were given of the design of the new suspension bridge over the Puget Sound, between the city of Tacoma and the Kitsap Peninsula, in the State of Washington, to replace the bridge which was destroyed by a storm in* 1940. *The following notes deal mainly with the erection of the bridge towers, the spinning of the cables and the erection of the suspended structure.*

IT will be recalled that there are four major differences between the designs of the old and the new Tacoma Narrows bridges, the second bridge having been built on the piers of its predecessor. The new bridge has a total width, centre to centre of stiffening girders, of 60ft, allowing for four lines of traffic, compared with the width of the old bridge of 39ft, permitting only two lines of traffic. The central suspended span remains unchanged at 2800ft, so that the span-to-width ratio of the bridge has been reduced from 72 to 47, the same value as that of the Golden Gate bridge at San Francisco. The bridge, as now constructed, is the third largest suspension bridge in the world. The total length of the structure from end to end of the anchorages is 5979ft, and the two side spans are 1100ft. The structural weight of the new bridge is 14,000 tons, compared with 8300 tons for the old span. The stiffening girders of the new bridge are open steel trusses, having a depth of 33ft, compared with the solid "I" beams of only 8ft depth, which were used in the design of the former bridge. The resulting stiffness of the trusses is approximately fifty-eight times that of the previous one. Finally, in designing the new span a number of precautions were introduced to prevent the occurrence of excessive torsional movement.

Reconditioning Work

The two main channel piers were undamaged by the failure of the former superstructure, and a thorough examination indicated that they could be used safely to support a wider and heavier bridge, since they were originally built with deep penetration, the weight of the piers themselves, exclusive of the weight of the superstructure, being 47,000 tons for the westerly pier and 59,000 tons for the easterly pier. To adapt the piers to the new, wider towers it was only necessary to remove the old concrete pedestals, which had a centre-to-centre distance of 50ft, and to replace them with new, higher pedestals spaced at 60ft centres. Because of the increased horizontal pull of the cables due to the greater weight of the new bridge, it was necessary to increase the weight of the anchorages. The total horizontal pull of the cables on the former anchorage was 28,000,000 lb, while the corresponding pull on the new anchorage is 36,000,000 lb. The required increase in weight was accomplished in the following manner. Approximately 13ft of concrete were removed from the sides of each anchorage by blasting down to the top of the footing block to make room for new anchor bars 60ft apart. These new anchor bars, to which the main cables were attached, were then set in place and embedded in new concrete, which extended the width of the old anchorage by 8ft in each direction. In addition, each anchorage was extended at the back by a distance of 20ft, forming a "U" around the remaining concrete core. Thus about 65 per cent of the old concrete was re-used in the new anchorage. The weight of each of the new anchors is approximately 36,000 tons.

Tower Erection

One erection derrick crane was used to erect both main bridge towers, the east tower being erected first. There were minor variations in the method and sequence used in the erection of each tower, but, in general, the procedure was as follows. The tower erection derrick was set up by means of a mobile crane on temporary steel columns which had been embedded in the new concrete pier pedestals. This structure was designed so as to keep clear of the area to be occupied by the tower legs. The 350,000 lb maximum reaction immediately under the derrick mast was carried by a truss 11ft deep and 60ft long, fabricated of 12in beams. The 150,000 lb maximum derrick sill reaction was carried by a 36in broad flange beam of 60ft span. The derrick had a 40ft mast, a 96ft boom, and an 18ft jib. The boom had a capacity of 27 tons at 60ft radius. The derrick was reeved with ⅞in wire hoisting rope, with five parts in the main load falls and thirteen parts in the boom topping falls. Power for the operation of the crane was provided by a three-drum hoist having a 165 h.p. torque converter drive. The hoist could develop a line pull of 20,000 lb on the sixth layer of ⅞in cable, and it required about eight minutes to hoist heavy loads to the tower top. The heaviest lifts encountered were tower sections in the base tier, which weighed 25 tons each.

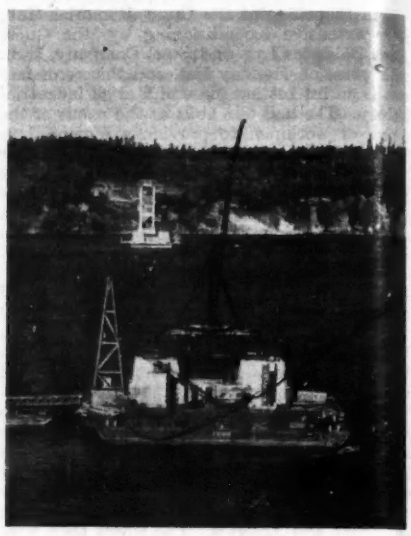


FIG. 2—ERECTION DERRICK ON EAST TOWER PIER

From the position at the tower base, called position O, the derrick crane erected the first two tower tiers, steelwork being hoisted from barges which were moored alongside the pier. Subsequently the derrick was "jumped" up the tower to position I, at the top of tier 2, and attached to the tower faces by means of four heavy structural brackets. Jumping was accomplished using two "catheads," which were set up at the top of the erected steel, one on each tower leg. Each cathead was equipped with a set of falls made up of eighteen 28in diameter sheaves operated with nineteen parts of ⅞in wire hoisting rope. These falls were connected at each end of the front truss supporting the derrick. Immediately under this connection point a 1in "transfer cable" was fastened. This cable ran down the tower, around a sheave, back up the tower and over the cathead, and down to the rear support beam of the derrick, to which it was connected with a turnbuckle. With this arrangement the front and rear of the derrick were raised during jumping at exactly the same speed, and the entire jumping weight was carried in the cathead falls. The stress in the transfer cables could be decreased by increasing the derrick boom radius. During jumping the boom was placed at a radius of 58ft to secure the desired stress of 15,000 lb to 20,000 lb in each transfer cable. The hoist used for jumping was similar to the one used for derrick operation. This hoist developed a line pull of 14,000 lb on two drums simultaneously, and was able to raise the derrick through a distance of about 70ft in ten minutes. The total jumping weight of the derrick was 230,000 lb. A complete jump required about two days—the first day to erect the catheads and to make all preparations, the

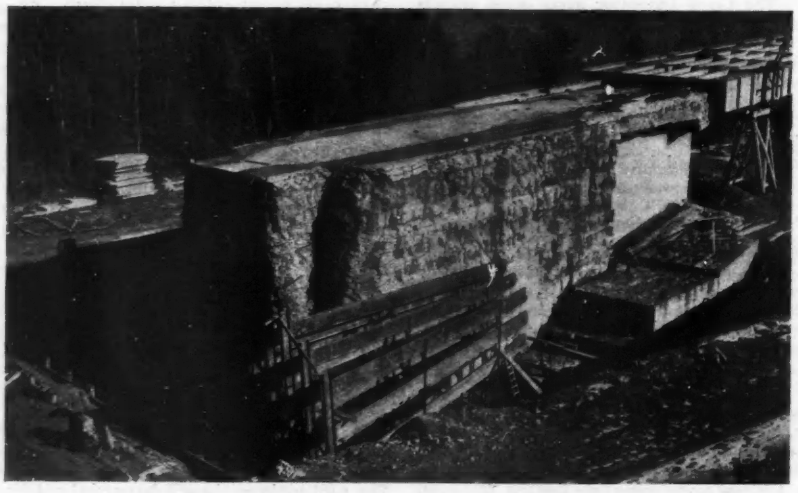


FIG. 1—ERECTION OF NEW WEST ANCHORAGE

second day to make the actual jump and to remove the jumping equipment. The derrick ascended the tower in this manner, erecting successive tiers of tower steelwork and bracing (Fig. 3). As each tier was erected, diaphragms and ladders were installed in the centre cell of the tower. Bracing members were picked up at one end by the derrick and lowered through the opening between the derrick floor and the tower leg. An auxiliary two-part set of falls hanging from the derrick underframe was then attached to the other end and the member manœuvred into place between the tower gusset plates.

The derrick erected tiers 12 and 13 from position 6 at the top of tier 11. In this position the crane was at an elevation of 430ft above the water level. The dismantling of the derrick and the erection of the remaining tower steelwork was accomplished (Fig. 4) by a 90ft boom erected at the top of one tower leg. The boom had a capacity of about 20 tons at 60ft radius. The foot of the boom was held by a heavy bracket connected to the shore side tower cell near the top of tier 12. A similar bracket at the top of tier 13 held the boom topping falls. Thus, the mast of the crane was formed by the top 36ft of the tower leg. The boom was swung by means of two sets of swing lines, which ran from the top of the boom down to the ends of outrigger brackets attached to the tower leg on the same level as the boom foot. Power for the operation of the crane was supplied by the jumping hoist.

In reconditioning the old piers, it had not been feasible to provide tower base anchors

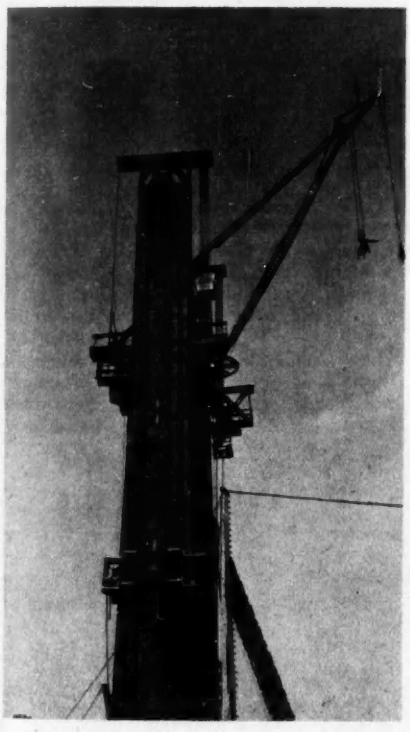


FIG. 3—DERRICK BEING "JUMPED" BY MEANS OF CATHEADS

running through the new concrete pedestals and deep into the main body of the old piers. Temporary outrigger erection frames (Fig. 5) were therefore provided to take erection moments at the base of the free-standing towers. These frames were designed to support the towers against a wind pressure of 40 lb per square foot. The vertical members transmitted downward forces to the outer walls of the cellular main piers, and resisted uplift by means of 70-ton counterweight boxes made of wood and filled with sand. The horizontal members of the frames were bolted to the top of the tower base plates and the sloping members were bolted to the top of the second tower tier.

Special L-shaped scaffolds were used during tower riveting operations. Four scaffolds were used to provide complete access around each tower leg. Each scaffold was supported by four parts of ⅜in cable. The scaffolds could be raised up the tower as riveting

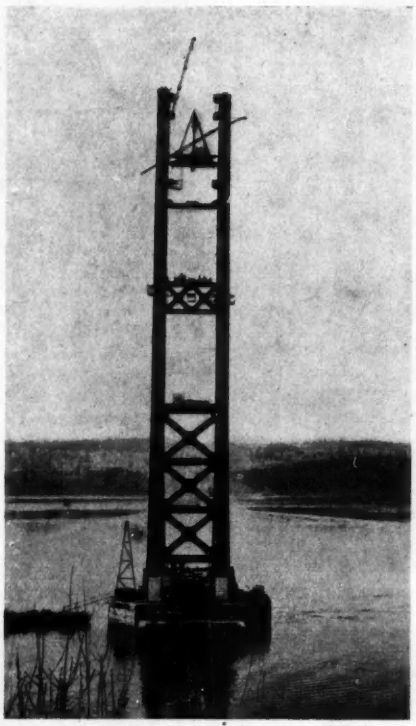


FIG. 4—DISMANTLING OF DERRICK CRANE

progressed by operating two manual hoists mounted on each scaffold. Before a horizontal tower splice could be riveted, it was necessary that the joint be "closed" all the way around to within about 0·010in. Immediately after each tier section was erected, the joint at its lower end would sometimes have openings of 0·030in or more. Addition of more weight proved to be the only sure means of getting the joints to close. For this reason, tower riveting operations had to remain several tiers behind the steelwork erection. The rivets were heated with soft coal forges and passed to the point of driving by means of pneumatic rivet blowers and flexible steel tubing. Rivets were driven with air-operated hammers and backed up with air-operated "hitting jacks." Four petrol-driven air compressors, each with a capacity of 210 cubic feet per minute, supplied the two main air lines which ran up the tower. The tower leg rivets were generally 1in in diameter, many being over 7in long. The rivets in the tower bracing were mostly ⅞in in diameter. Altogether there were 146,000 field rivets in the two towers.

Early in the tower erection a temporary man-hoist was installed to carry men and supplies. The man-hoist cage had a capacity of about 20 men and could make the journey to the tower top in three minutes. The drive was obtained from a single-drum petrol-driven hoist, built especially for man-hoist operation. The cage was guided up the tower by two cables which were each stressed to 20,000 lb by concrete counterweight blocks. Timber beams held the guide cables in position at each tower strut man-hoist landing. These landings also served as storage platforms and operating areas for men working in the tower legs. A steel platform hung underneath the erection derrick served as the top man-hoist landing. The man-hoist cables were handled at the upper end by a sheave beam fastened underneath the derrick. After the derrick was dismantled, the sheave beam was fastened to the tower bracing so that the man-hoist could continue in operation.

During the latter stages of erection on the east tower, a disastrous earthquake struck the Pacific North-West of the United States. At the time, the dismantling of the derrick crane had been completed and the erection of the final pieces of tower bracing was proceeding. The tremors started a few minutes before noon on April 13, 1949, and lasted about thirty seconds. A 20-ton cable saddle, which had been erected a few days earlier, was thrown southward off the top of the south tower leg and fell 500ft, punched a hole in the work scow moored to the pier, and went on down to the bottom of the Sound. The scow subsequently turned over and was carried away by the rushing incoming tide. No casualties were suffered and there was no damage of any kind to the steelwork. The fallen saddle was found in 140ft of water by a diver, and recovered and replaced at the tower top, but the work scow toolshed, with a large stock of small tools, was lost. Three air compressors also went to the bottom, but they were salvaged and

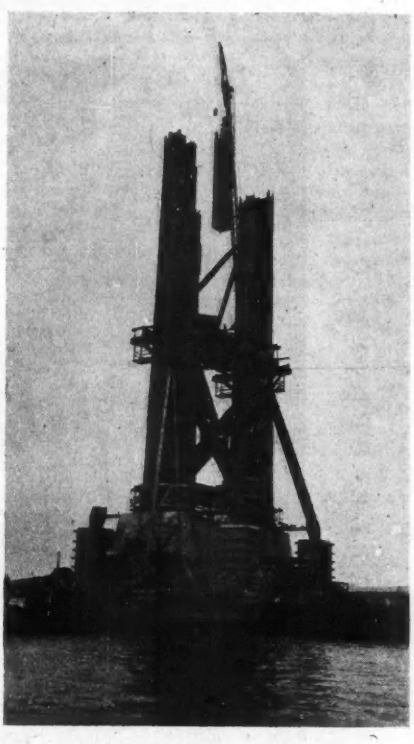


FIG. 5—BASE OF TOWER WITH ERECTION FRAMES

reconditioned. Thus occurred what must be one of the most unusual accidents in the history of bridge building. The earthquake intensity in the Tacoma area was later established at 7 on the modified Mercalli intensity scale of 1931.

During the latter stages of erection of the west tower, another unfortunate accident took place. At the time the derrick was in the topmost position and had completed

CABLE SPINNING AT THE TACOMA NARROWS BRIDGE

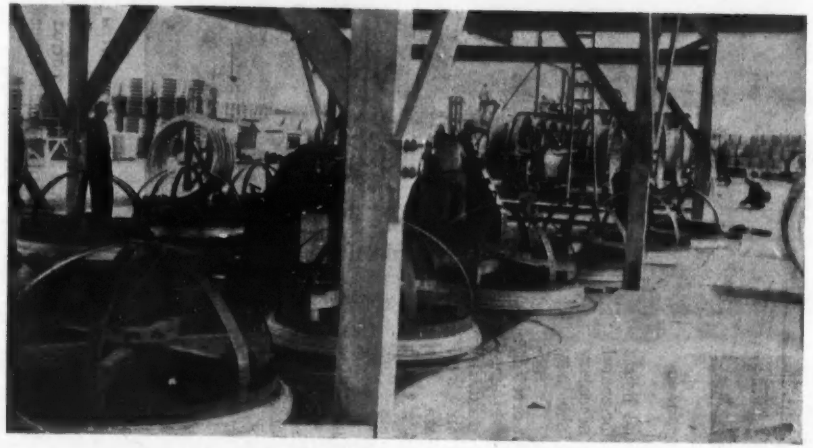
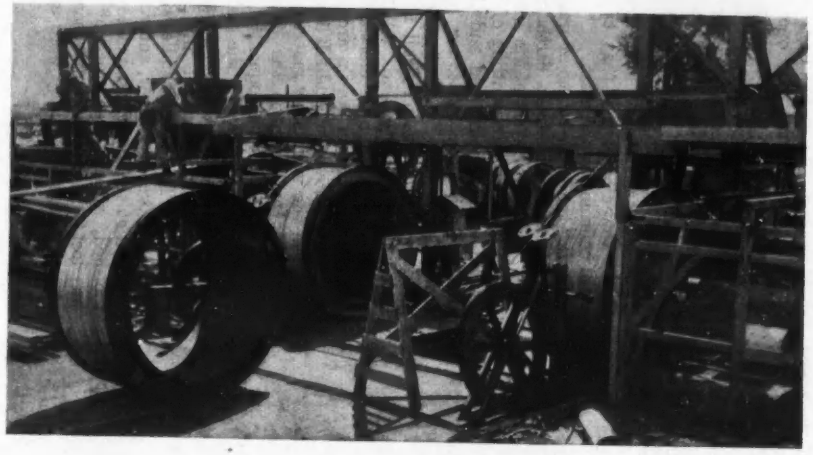


FIG 6—FIRST STAGE WIRE REELING



F.G. 7—SECOND STAGE WIRE REELING

FIG. 8—GROUP OF UNREELING MACHINES ON EAST ANCHORAGE

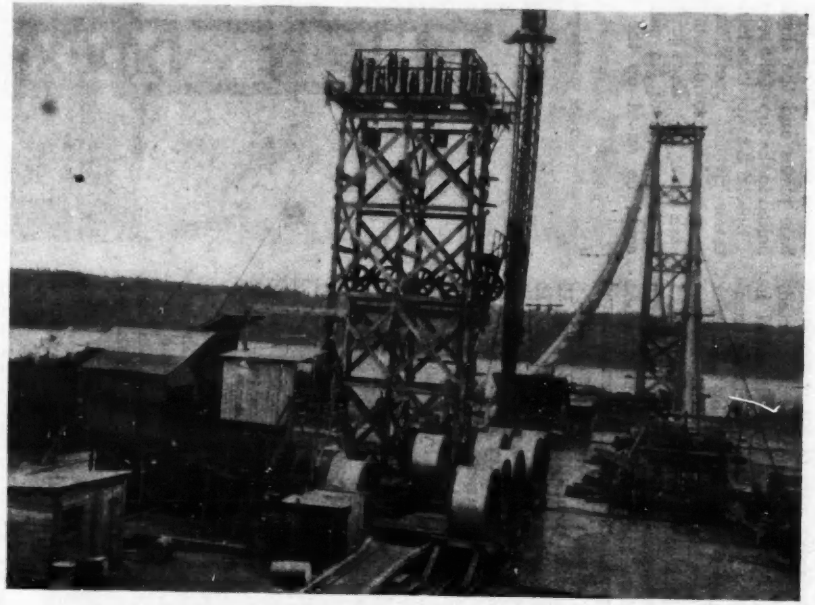


FIG. 9—COUNTERWEIGHT TOWER AND "TRAMWAY" DRIVE CONTROL

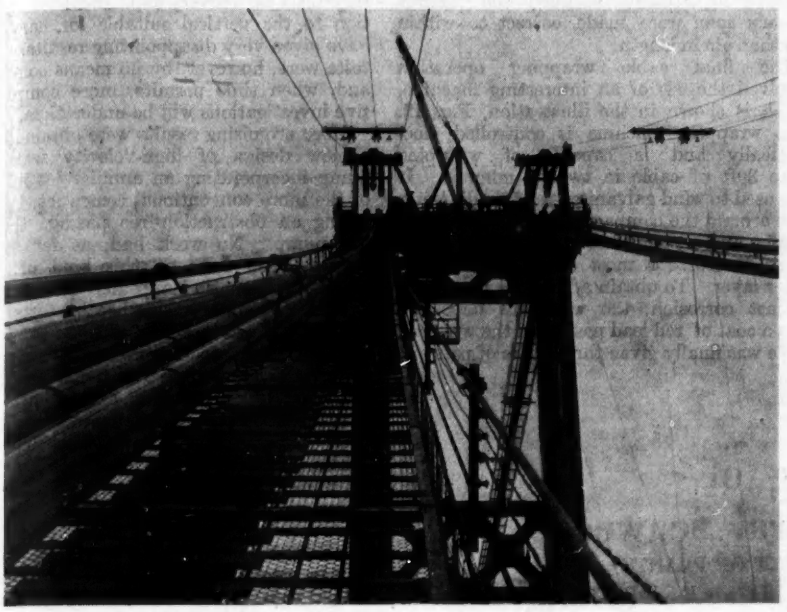


FIG. 10—FOOTBRIDGE AND CABLE STRANDS NEAR TOWER TOP

the erection of the tower leg steelwork. Shortly before midnight on June 7, 1949, a fire started in some electrical wiring at the north end of the pier and spread quickly around the creosoted timber pier fender. The flames exploded several drums of petrol, throwing fire in every direction and igniting the man-hoist landing platforms and the derrick crane deck. The tower was ablaze from bottom to top. A short while later the derrick boom line burned through and the boom dropped and buckled around the south front derrick bracket. Fire tugs arrived at the scene and fought the flames for several hours. Timber installations on the pier

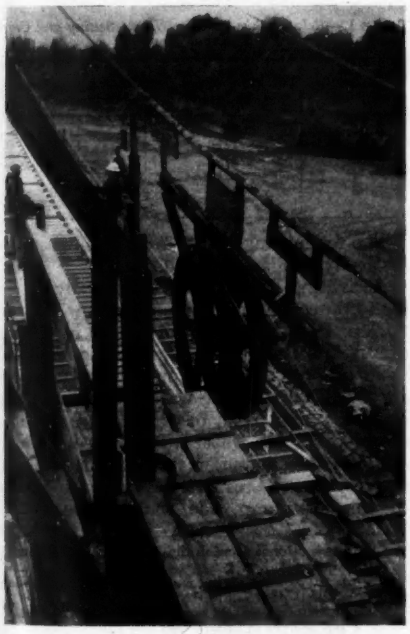


FIG. 11—SPINNING WHEEL ASSEMBLY

were reduced to a charred mass of ruins and all erection equipment was lost, except the jumping hoist, which was repaired by the field forces. However, careful inspection disclosed no damage whatsoever to the steelwork on the pier. Erection of the east tower was begun early in January, 1949, and was completed in June. Work was begun on the west tower early in April, 1949, a few days before the earthquake, and was completed early in July, 1949.

CABLE SPINNING

The cable contractor started preparatory work at the site in the spring of 1949 and both towers were turned over to him in July of that year. The main cables are spaced 60ft apart and have a sag ratio of 1/10. Each wrapped cable is 20¼in in diameter, and contains about 252 square inches of steel wire having an ultimate tensile strength of 225,000 lb per square inch. Each of the main cables is made up of a total of 8702 individual galvanised bridge wires, 0·196in in diameter and spun in nineteen strands of about 460 wires each. The bridge suspender cables consist of four parts of 1⅜in wire rope and are spaced at 30ft intervals.

A complete wire reeling plant was set up at a site some 7 miles from the bridge. The plant received the 0·196in diameter bridge wire in 5ft diameter coils weighing about 375 lb and comprising approximately 3500ft of wire. A first stage reeling operation resulted in the production of 3200 lb spliced intermediate reels. Subsequently, in a second stage reeling operation, the wire from the intermediate reels was transferred to the spinning reels proper, which are 7ft in diameter, weigh about a ton and are able to carry 8 tons or 180,000ft of wire (Figs. 6 and 7).

Prior to the commencement of cable spinning operations, a guyed derrick was set up on the east anchorage, which was to be the cable contractor's base of operations. Stiff-leg derrick cranes were erected on the west anchorage and at the top of each of the main towers. The erection of the foot bridges commenced in July, 1949. Each foot bridge was supported by ten 1in bridge strands and decked with wire mesh and removable timber sections (Fig. 10). Five crosswalks were used between the two foot bridges, three in the main span and one in each side span. The "tramway" haulage systems were then installed. As it was desired to spin two strands simultaneously, a duplicate set of tramway ropes and spinning wheels were set up—one for each main cable. Furthermore, as is shown by the illustration Fig. 11, each spinning wheel assembly comprised two sheaves, thus facilitating two loops or four wires to be carried over during each journey of each spinning wheel. The two tramway haulage systems were supported across the spans by two pairs of 1 $\frac{9}{16}$in bridge strands, which were supported at the top of each main tower and at the cable splay points.

The wire unreeling machinery was set up on the east anchorage, and all cable wire was to be pulled across from east to west. The illustrations, Figs. 8 and 9, show the tandem group of four unreeling machines and the spinning wire counterweight tower and tramway drive control on the east anchorage. Actual cable spinning began on October 17, 1949, and was completed on

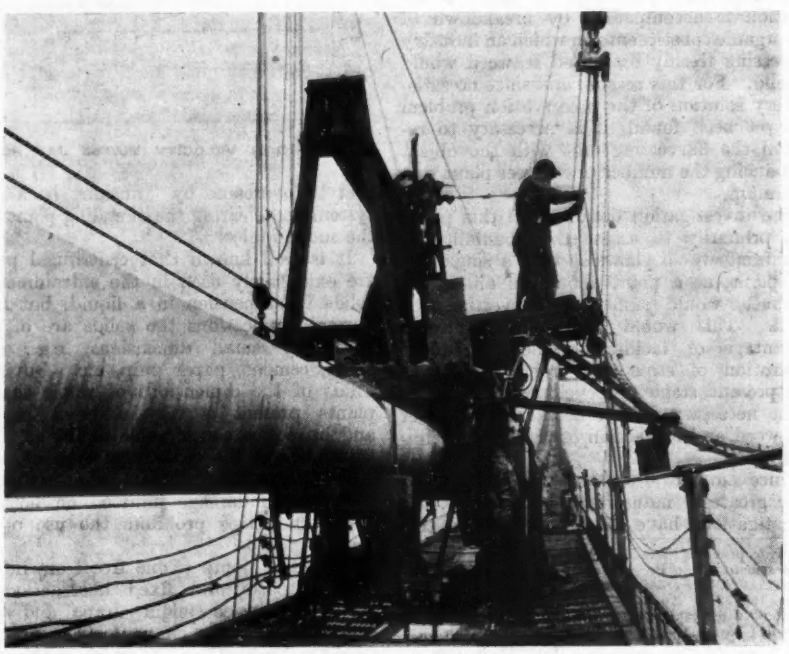


FIG. 12—CABLE WRAPPING MACHINE

January 16, 1950. Cable compaction was completed on February 15th, and the erection of cable bands and suspenders was finished on March 13th. The winter of 1949–50 was notable for high winds and bad weather, and on several occasions the cable spinning operations had to be suspended temporarily. The wrapping of the cables was begun late in May, 1950, and was completed in July. It is of interest to note that any adjustment of the suspension cable guide wires and of the completed cable strands had to be performed at night so as to ensure that all portions of the steel wire in strands previously adjusted, and in strands under adjustment at the time would be at the same temperature. According to the cable contractor, actual relative adjustments between the strands in each span were made correct to within less than $\frac{1}{8}$in in length.

The final cable wrapping operation involved the use of an interesting machine, which is shown in the illustration, Fig. 12. This wrapping machine is controlled electronically and is capable of wrapping some 30ft of cable in twenty minutes. It was used to wind galvanised 0·150in diameter wire around the compacted cables under such tension and in such close wire-to-wire contact so as to create a most effective protective outer layer. To obtain additional protection against corrosion, the wire was deposited into a coat of red lead paste and the wrapped cable was finally given three coats of paint.

(To be continued)

Harvesting of Brown Sub-Littoral Seaweeds

No. IV.—ENTRAINMENT OF PLANTS*

By PHILIP JACKSON, M.Sc., M.I.Mech.E., M.I.Chem.E., F.R.S.E., and IAN B. MACDUFF, B.Sc.

Machinery is being devised for the commercial harvesting of British sub-littoral seaweeds. Two main principles are being investigated, namely, tearing the weed from the sea bed and raising it to the surface mechanically and cutting the weed from the sea bed and raising it by entrainment in water. Results of tests on a water jet pump for entraining cut weed continuously to the surface are reported.†

ONE of the principal problems in the application of the cutting and entrainment principle to the harvesting of sub-littoral seaweed is to devise means of entraining the weed from the sea bed to the surface without choking or jamming, and without inflicting damage on the weed.

Mackenzie (1947) has described the first investigations of this principle, in which the prototype unit cut the frond into small pieces, which were then pumped to the surface in suspension in water by a conventional centrifugal type pump. From the entrainment angle this proved to be very suitable but it has been pointed out by Jackson (1952) that the increased rate of decomposition resulting from the excessive cutting presents a very serious problem in commercial operations, in that decomposition is accompanied by breakdown of the organic constituents on which an industry processing freshly harvested seaweed would depend. For this reason, and since no satisfactory solution of the preservation problem has yet been found, it is necessary to redesign the harvesting unit with the object of reducing the number of cuts per plant to a minimum.

The investigation described in this paper was primarily to assess the possibility of entraining whole plants so that a single cut per plant, at a point about 6in above the holdfast, would suffice in harvesting the weed. This would have the additional advantage of facilitating the subsequent separation of stipe and frond, which, at the present stage of development, appears to be necessary for the economic drying of the weed and extraction of the algal chemicals.

Since *Laminaria cloustoni* has, at present, the greatest industrial significance, the investigations have been restricted to this species. It is reasonable to assume that *L. digitata* would behave similarly to *L. cloustoni* but that *L. saccharina* will present different entrainment problems, and will require to be investigated separately, because of its high proportion of frond. One of the difficulties with *L. cloustoni* is occasioned by epiphytic growths of *L. digitata*, which prevent the plant entering the entrainment system without further cutting. Fortunately the indications are that such growths are comparatively infrequent and it is considered that this difficulty could therefore best be overcome by "flushing back" the system and clearing the offending plant from the suction inlet.

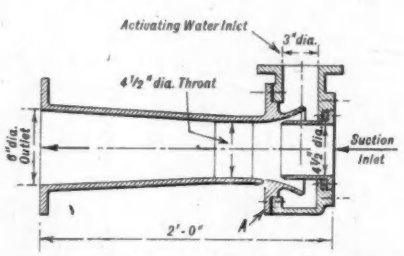


FIG. 1—HIGH VELOCITY WATER JET PUMP

It is well known that centrifugal pumps are extensively used in the entrainment of solids in suspension in a liquid, but in all normal applications the solids are of comparatively small dimensions, e.g., sand, ashes, cement, paper pulp, &c. Obviously solids of the dimensions of whole seaweed plants present a very different problem and introduce considerable doubt as to the suitability of the centrifugal type of pump. Rough tests have, in fact, shown that the considerable damage inflicted on both the frond and stipe prohibits the use of this kind of pump.

The ideal pump is one free from internal moving parts and fixed obstructions on which the weed might drape and cause blockage or suffer damage. The first and obvious kind of pump which fulfils these conditions is the air-lift pump, but exploratory tests at delivery pipe angles of inclination to the vertical suitable for harvesting have given very disappointing results. These tests were, however, by no means conclusive and, when time permits, more comprehensive investigations will be undertaken.

More promising results were obtained with a new design of high-velocity water jet pump incorporating an annular jet in place of the more conventional centre jet, thereby giving an obstruction-free passage through the pump. No work had, as far as was known, been done on this kind of pump and no information appeared in the literature. Preliminary small-scale tests gave sufficiently encouraging results to justify further and more comprehensive investigations on a larger scale and under conditions more nearly approaching actual harvesting conditions. This paper is mainly concerned with these larger scale investigations.

The operation of the high velocity water jet pump relies on the energy of activating water supplied to the pump being converted from pressure to velocity in passing through a converging nozzle. The consequent reduction in pressure in the chamber surrounding the jet causes a flow of water along the suction pipe, which meets the activating water and goes forward as a combined stream into the diverging discharge pipe, the energy being partially reconverted to pressure energy, which raises the combined mass of water against the discharge head.

The nomenclature is detailed in a footnote‡.

EXPERIMENTAL EQUIPMENT

Details of the high-velocity water jet pump are given in Fig. 1. This pump was designed with a 4½in diameter suction, a 6in diameter discharge and a 3in diameter activating water supply to the nozzle, and was constructed in two parts to permit variation in nozzle area by means of the packing plates inserted at *A*. The relationship between nozzle area and thickness of packing plate is given in Table I.

TABLE I.—*Relationship Between Nozzle Setting and Cross Sectional Area*

Nozzle setting	Thickness of packing plate, in	Cross sectional area of nozzle, in²
1	0	1·68
2	1/16	1·79
3	1/8	1·92
4	3/16	2·05
5	1/4	2·16

The test arrangements are shown diagrammatically in Figs. 2, 3 and 4.

Activating water was supplied by a 4in high-lift centrifugal pump driven from a 30 h.p. Ford "V8" petrol engine by means of "V" belts, giving a pump-engine speed ratio of 1·47 : 1. The pump was rated to supply 300 g.p.m. of water when pumping against a total head of 112ft, at a speed of 1600 r.p.m. Sea-water was pumped through 4in and 3in diameter flexible suction and delivery hoses, respectively, to the nozzle of the jet pump, the suction hose being

* The previous articles were as follows: No. I—"Assessment of the Problem and Review of Preliminary Experiments," May 30th, pages 718–720, and June 6th, pages 750–751; No. II—"The Continuous Grapnel Method," June 20th, pages 814–817, June 27th, pages 846–851; No. III.—"Use of Reciprocating Cutters," July 4th, pages 2–5.

† Patent applications have been submitted to cover the equipments described in this article.

‡ A = cross sectional area of annular nozzle of jet pump, square inches.
Q = quantity of activating water supplied to jet pump, gallons per minute.
Q_s = quantity of water entering jet pump suction, gallons per minute.
P_g = gauge pressure of activating water supply to jet pump, lb per square inch.
h = equivalent head of activating water, feet.
h_s = static head on jet pump suction, feet.
h_d = static head on jet pump delivery, feet.
H = total static head on pump, feet.
L = total length of entrainment system, feet.
R_s = radius of suction bend on jet pump, feet.
V_d = velocity of flow in discharge pipe, feet per second.
V_s = velocity of flow in suction pipe.
E = efficiency = $\frac{Q_s(h_d+h_s)}{Q(h-h_d)}$ (Gibson, 1924).

fitted with a conventional foot valve and strainer.

The total quantity of water discharged from the jet pump was measured in a calibrated tank C (Fig. 2), and the quantity and pressure of activating water by an orifice meter inserted at D and pressure gauges connected at E and F, respectively. A tachometer was used to measure the speed of the activating water supply pump.

For the purposes of the tests, seaweed was fed into a 12in square wood stand pipe (G, Fig. 2), connected to the jet pump suction bend by a tapered bend carrying a branch H through which sea-water was admitted. The weed sank in the stand-pipe until it came under the influence of the flow of water into the jet pump suction. In later tests the connection between the stand-pipe and the pump suction was removed and the seaweed allowed to sink into a galvanised wire mesh basket J, (Fig. 3), into which projected a bell-mouthed fitting connected to the end of the suction bend. Finally, in the hand feed experiments, weed was presented direct to the pump suction at various distances from the bell-mouthed entrance (Fig. 4).

The jet pump suction and discharge pipelines were in mild steel with rubber bends; the activating water supply pump suction and discharge pipelines were rubber throughout.

The complete equipment was mounted on a wood jetty with a straight drop into 3–4 fathoms of water.

The Significance of Certain Theoretical Considerations in Practice

It is clear from theoretical considerations that (*a*) because the loss of energy due to eddy formation in the diverging discharge pipe from the high velocity water jet pump is proportional to V_d^2 and will therefore increase as h_d increases, the efficiency of the pump will increase as the suction lift (h_s) is increased at the expense of delivery lift (h_d); (*b*) operating the pump with its axis inclined to the vertical should effect no significant change in efficiency and (*c*) streamlining the suction inlet should tend to reduce the losses at inlet and therefore increase efficiency.

These conclusions, which have an important bearing on the practical application of this system of pumping to the problem of entraining cut seaweed from the sea bed, were confirmed by the results of tests, typical of which are those recorded in Tables II, III, IV.

Table III.—*Effect of Inclining Axis of Jet Pump on Pump Performance*
—Nozzle setting = 5, $h_s = 0$, $h_d = 10$–11ft

P_g, Lb/in²	Q, g.p.m.	Q_s, g.p.m.	Q_t, g.p.m.	E, Per cent
Axis vertical				
35	386	314	700	11·5
35	386	324	710	11·9
35	386	334	720	12·3
35	386	334	720	12·3
35	386	334	720	12·3
37	397	403	800	13·5
37	397	403	800	13·5
Axis inclined at 45 deg.				
36	391	349	740	13·7
36	391	359	750	14·1
36	391	359	750	14·1
37	396	364	760	13·7
36	391	369	760	14·5
36	391	359	750	14·1
36	391	359	750	14·1

Table IV.—*Effect of Streamlining Suction Inlet*
(Nozzle setting = 5, $h_s = 0$, $h_d = 9$ft)

P_g, lb/in²	Q, g.p.m.	Q_s, g.p.m.	Q_t, g.p.m.	E, per cent
Bell-mouthed suction				
38	402	378	780	10·8
38	402	398	800	11·4
38	402	398	800	11·4
38	402	398	800	11·4
40	412	428	840	11·3
40	412	428	840	11·3
40	412	428	840	11·3
Parallel bore suction				
39	407	393	800	10·8
39	407	393	800	10·8
40	412	408	820	10·7
40	412	398	810	10·5
40	412	398	810	10·5
39	407	393	800	10·8

Since efficiency increases as h_d decreases the pump should, for maximum efficiency be located as near as possible to delivery level. Other significant advantages of this arrangement are that it (i) permits the use of a short activating water supply pipeline, thereby reducing pressure drop to a minimum; (ii) restricts the number of pipes "breaking" the surface to the one suction pipe of the jet pump and consequently reduces navigational difficulties; (iii) facilitates work on the jet pump in situ and (iv) simplifies the supporting structure.

The angle of inclination of the axis of the pump affects the lining up of the entrainment system, and any measure which tends to eliminate changes in direction of flow increases the effectiveness of entrainment.

It is certain that the successful inducement of whole seaweed plants to enter the entrainment system after cutting from the sea bed will necessitate some form of streamlining if straddling and choking are to be avoided. It is axiomatic that any improvement in shape of suction which facilitates the entry of seaweed will reduce the hydraulic losses at entry and increase the efficiency.

Because of limitations imposed by the experimental equipment it was not always possible during the tests to satisfy the conditions set out above, but wherever possible every attempt was made to do so.

Table II—*Effect on Pump Performance of Increasing Suction Lift (h_s) in a Given Total Lift (H)*

Nozzle setting 3 $P_g = 40$ lb/in² $h_s = 1$ft. $h_d = 8$ft $H = 9$ft					Nozzle setting 3 $P_g = 40$ lb/in² $h_s = 4$ft. $h_d = 5$ft $H = 9$ft				
P_g, lb/in²	Q, g.p.m.	Q_s, g.p.m.	Q_t, g.p.m.	E, per cent	P_g, lb/in²	Q, g.p.m.	Q_s, g.p.m.	Q_t, g.p.m.	E, per cent
40	384	416	800	11·6	40	384	566	950	15·2
40	384	406	790	11·3	40	384	556	940	15·0
41	391	409	800	10·9	40	384	556	940	15·0
40	384	406	790	11·3	40	384	556	940	15·0
40	384	406	790	11·3	40	384	546	930	14·7
40	384	396	780	11·1	40	384	546	930	14·7
40	384	406	790	11·3	40	384	556	940	15·0
40	384	406	790	11·3	40	384	546	930	14·7
Nozzle setting 5 $P_g = 30$ lb/in² $h_s = 0$. $h_d = 10$ft $H = 10$ft					Nozzle setting 5 $P_g = 30$ lb/in² $h_s = 3$ft. $h_d = 7$ft $H = 10$ft				
30	357	183	540	8·7	30	372	328	700	14·2
30	357	203	560	9·6	30	372	338	710	14·7
30	357	163	520	7·7	30	372	338	710	14·7
30	357	183	540	8·7	30	372	338	710	14·7
30	357	193	550	9·2	30	372	318	690	13·8
30	357	203	560	9·6	30	372	328	700	14·2
30	357	203	560	9·6	30	372	338	710	14·7
30	357	203	560	9·6	30	372	338	710	14·7

Entrainment with Closed Feed System

Entrainment.—Investigations to assess the suitability of the jet pump for use in the entrainment of whole seaweed plants were

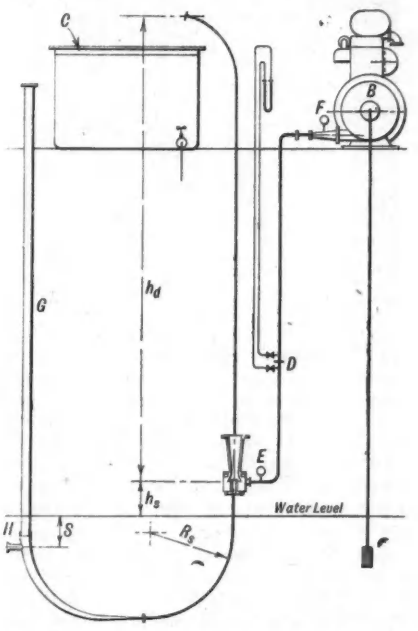


Fig. 2—Diagram of Equipment for Closed Feed Tests

conducted in two stages: (*a*) with a closed feed system, the plants being guided to the pump suction, and (*b*) with an open feed system, the plants being guided only to a predetermined distance from the pump suction. For convenience and to permit observation of the plants at the suction intake, the first tests with a closed feed system were conducted with a shallow suction, viz., from about 1ft 6in below the water surface.

The arrangement of the test rig was generally as indicated diagrammatically in Fig. 2. h_s and h_d were kept constant at 1ft and 7ft, respectively, the radius of the suction bend R_s was 3ft 6in and the total length L of the entrainment system from suction port to discharge was about 23ft. Activating water was supplied at 40 lb per square inch for nozzle settings 1 and 3, and 35 lb per square inch for setting 5.

Whole plants were fed singly and in batches of two and three together and the times taken from entering the suction intake to leaving the discharge pipe recorded. Knowing p_g and H, and since the concentration of seaweed in the weed-water mixture and, consequently, the hydraulic losses due to the relative motion of the water with respect to seaweed, were comparatively low, the approximate values of Q and Q_s were read from the pump performance curves.

The results are given in Table V.

Most of the plants were entrained successfully and without damage, at all three nozzle settings, although there was slight evidence of split fronds in one or two cases.

TABLE V—*Comparison Between Entrainment Times at Different Nozzle Settings for Single Plants and Groups of Plants (Closed Feed System and Shallow Suction)*

Setting 1: $A = 1 \cdot 68 in^2$. Setting 3: $A = 1 \cdot 92 in^2$. Setting 5: $A = 2 \cdot 16 in^2$. Average size of 164 plants used: 4ft 0½in stipe, 1ft 4½in. frond

Setting 1			Setting 3			Setting 5		
$h_s = 1ft$, $h_d = 7ft$ $P_g = 40$ lb/in² $Q = 340$ g.p.m. $Q_s = 400$ g.p.m.			$h_s = 1ft$, $h_d = 7ft$ $P_g = 40$ lb/in² $Q = 385$ g.p.m. $Q_s = 460$ g.p.m.			$h_s = 1ft$, $h_d = 7ft$ $P_g = 35$ lb/in² $Q = 395$ g.p.m. $Q_s = 430$ g.p.m.		
Frond or stipe first	Entrainment		Frond or stipe first	Entrainment		Frond or stipe first	Entrainment	
	No. of plants	Time, seconds		No. of plants	Time, seconds		No. of plants	Time, seconds
Frond ...	1	10	Frond ...	1	5	Frond ...	1	7
Frond ...	1	12	Frond ...	1	5	Frond ...	1	6
Frond ...	1	13	Frond ...	1	7	Frond ...	1	10
Frond ...	1	23	Frond ...	1	8	Stipe ...	1	15
Frond ...	1	55	Frond ...	1	6	Stipe ...	1	60
Frond ...	1	15	Frond ...	1	40	Frond ...	1	10
Frond ...	1	11	Frond ...	1	9	Frond ...	1	8
Frond ...	1	9	Frond ...	1	*	Frond ...	1	50
Frond ...	1	*	Frond ...	1	10	Frond ...	1	12
Frond ...	1	*	Frond ...	1	8	Frond ...	1	10
Frond ...	1	*	Frond ...	1	6	Frond ...	1	13
Frond ...	1	14	Stipe ...	1	12	Frond ...	1	11
Frond ...	1	12	Stipe ...	1	30	Stipe ...	1	*
Frond ...	1	12	Frond ...	1	8	Stipe ...	1	40
Frond ...	1	15	Frond ...	1	5	Frond ...	1	15
Frond ...	1	15	Frond ...	1	6	Frond ...	1	15
Frond ...	1	13	Frond ...	1	8	Frond ...	1	8
Frond ...	1	14	Frond ...	2	8	Frond ...	2	15
Frond ...	1	13	Frond ...	3	5	Frond ...	4	20
Stipe ...	1	65	Frond ...	5	10	Frond and stipe	4	*
Frond ...	1	25	Frond ...	6	18			
Frond ...	2	14	Frond and stipe	6	24	Frond ...	5	27
Frond ...	3	17				Frond ...	5	30
Frond ...	4	18	Frond ...	7	16	Frond and stipe	6	*
3F–2S ...	5	21	Frond and stipe	7	15			
Frond ...	6	26				Frond ...	6	*
Frond ...	6	29	Frond and stipe	8	*	—	—	—
Frond ...	7	*				—	—	—

* Permanent choke—necessitating dismantling to clear.

Also, it will be seen from Table V that most of the runs were accomplished without choking. Nevertheless, the relatively small proportion of runs in which choking did occur would be too high for commercial operations.

The most vulnerable parts of the system appeared to be the feed pipe and suction bends. The former would not, of course, be used in practice, its only function being to provide a means of controlling the feed of plants to the suction intake in the tests, and its removal should appreciably reduce the frequency of choking. As would be expected, choking is more prevalent when the plants are presented stipe first, four out of thirteen, or 30·8 per cent, presented this way causing choking, compared with only six out of sixty-four, or 9·8 per cent, presented frond first.

The velocities of flow in the suction, discharge and activating water pipelines during the tests were approximately:—

	Setting 1, ft/sec	Setting 3, ft/sec	Setting 5, ft/sec
Suction	9·65	11	10·4
Discharge	10·1	11·5	11·2
Activating water ...	18·5	21	21·6

To simulate more nearly practical operating conditions, the length of suction pipe was increased to pump water from a depth of about 3 fathoms, giving a total length of entrainment system of about 41ft. The radius of the suction bend was slightly increased from 3ft 6in to 4ft and another series of tests carried out, giving the results tabulated in Table VII.

The chokages when the plants were presented stipe first were about the same as in the previous tests, viz., about 60 per cent, but there was a marked increase from about 14 per cent to 27 per cent when the plants were presented frond first, although these were again considerably less frequent than when presenting the plants stipe first.

Effect of Radius of Suction Bend with Closed Feed.—Because of the troubles occasioned by choking in the previous tests, it was decided to devote some time to investigating this problem in more detail. The visual indications were that most of the choking was occurring in either the feed pipe bend connecting the feed pipe to the suction bend, or the suction bend itself.

Since it was the intention to use the same jet pump and the same sizes of pipe in the first prototype cutting and entrainment unit, two series of tests were conducted to determine the minimum radius of 4½in diameter suction bend which would permit free passage of the plants.

In the first tests the system was arranged as in the previous shallow-suction tests, to facilitate observation of the behaviour of the plants when entering the suction intake. h_s and h_d were again kept reasonably constant at 1ft and 7ft, respectively, and the total length of the entrainment system was again about 23ft. Activating water was supplied at a pressure of 40 lb per square inch. As the radius of the suction bend was varied, so the depth of the suction port below the water surface varied between 1ft and 4ft.

The results are given in Table VI.

It is evident from Table VI that up to and including a 4ft radius there is considerable risk of choking, but any greater radius appears to be perfectly satisfactory under the conditions of the tests. There was not the slightest evidence of damage to the plants at suction bend radii above 4ft, but at this radius some of the fronds were slightly damaged and at lower radii the damage was fairly extensive. The velocities of flow in the suction, discharge and activating water supply pipe-lines were as in the previous tests.

As previously mentioned, it appeared that the bend connecting the feed pipe to the pump suction bend was contributing largely to the choking which was occurring; to permit a more reliable assessment to be made of the minimum radius of suction bend suitable for use in the prototype harvester, tests were next conducted with the feed bend removed.

TABLE VII.—*Comparison Between Entrainment Times at Different Nozzle Settings for Single Plants and Groups of Plants (Closed Feed System and Deep Suction).*

Setting 3: $A = 1 \cdot 92$ in². Setting 5: $A = 2 \cdot 16$ in². Average size of seventy-six plants used: 4ft 0½in stipe, 1ft 4½in frond.

Setting 3			Setting 5		
$h_s = 1ft$. $h_d = 7ft$ $p_g = 40$ lb/in² $Q = 385$ g.p.m. $Q_s = 460$ g.p.m.			$h_s = 1ft$. $h_d = 7ft$ $p_g = 35$ lb/in² $Q = 395$ g.p.m. $Q_s = 430$ g.p.m.		
Frond or stipe first	Entrainment		Frond or stipe first	Entrainment	
	No. of plants	Time, sec		No. of plants	Time, sec
Frond ...	1	10	Frond ...	1	18
Frond ...	1	12	Frond ...	1	14
Frond ...	1	20	Frond ...	1	15
Frond ...	1	8	Frond ...	1	*
Stipe ...	1	*	Frond ...	1	30
Frond ...	1	30	Stipe ...	1	25
Frond ...	1	8	Stipe ...	1	*
Stipe ...	1	28	Frond ...	1	28
Stipe ...	1	42	Frond ...	1	17
Frond ...	1	12	Frond ...	1	14
Frond ...	1	*	Frond ...	1	12
Frond ...	1	15	Frond ...	1	*
Frond ...	1	20	Frond ...	1	*
Frond ...	1	18	Frond ...	1	43
Frond ...	1	25	Frond ...	2	28
Frond ...	2	28	Frond ...	2	36
2F–1S ...	3	20	2F–1S ...	3	65
Frond ...	3	29	Frond ...	3	48
2F–2S ...	4	22	Frond ...	3	32
Frond ...	4	63	2F–2S ...	4	*
3F–2S ...	5	*	Frond ...	4	*
Frond ...	5	*	—	—	—

* Permanent choke, necessitating dismantling to clear.

ENTRAINMENT WITH OPEN FEED SYSTEM

Effect of Radius of Suction Bend with Open Feed.—The arrangement of the system for these tests is shown diagrammatically in Fig. 3, the weed being fed to a steel mesh basket *J*, into which projected the bell-mouthed fitting connected to the suction bend of the jet pump. The depth of the basket below the water surface varied between 1ft 6in and 4ft, this variation being due to the ebb and flow of the tide. The average distance of the plants entering *J*

TABLE VI—*Effect of Radius of Suction Bend on Choking with a Closed Feed System*

Nozzle setting 3 ($A = 1 \cdot 92 in^2$), $p_g = 40$ lb/in², $Q = 385$ g.p.m., $h_s = 1ft$, $h_d = 7ft$, average size of plant = 4ft stipe, 1ft 6in frond

Radius of bend, R_s, feet	Frond or stipe first	Entrainment		Radius of bend, R_s, feet	Frond or stipe first	Entrainment	
		No. of plants	Time, seconds			No. of plants	Time, seconds
6	Frond	1	5	4	Frond	1	8
6	Frond	1	6	4	Frond	1	6
6	Frond	1	6	4	Frond	1	10
6	Frond	1	7	4	Frond	1	5
6	Stipe	1	10	4	Stipe	1	50
6	Frond	2	5	4	Stipe	2	*
6	Frond and stipe	3	4	4	Frond	3	30
				3	Frond	1	10
5	Frond	1	5	3	Frond	1	*
5	Frond	1	5	3	Frond	1	*
5	Frond	1	7	3	Stipe	1	*
5	Stipe	1	14	3	Stipe	1	*
5	Stipe	1	9	3	Frond	2	*
5	Frond	2	6	3	Frond	3	*
5	Frond	3	8	—	—	—	—

* Choke

from the entrance to the bell-mouthed suction fitting was about 9in.

Heads h_s and h_d were kept approximately constant at 1ft and 5ft, respectively; this reduction in delivery head to a figure more nearly approaching what it would be in practice than in the previous tests, was made possible by the state of the tide at the time of the tests. Activating water was again supplied at 40 lb per square inch

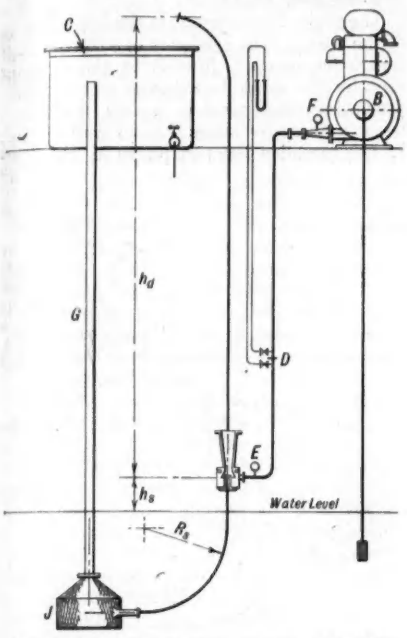


FIG. 3—DIAGRAM OF EQUIPMENT FOR OPEN FEED TESTS

and the total length of the entrainment system L was reduced to about 19ft.

Tests were run at four different radii of suction bend, 5ft, 4ft, 3ft, and 2ft, and the plants were in all cases presented frond first.

The results given in Table VIII indicate that the removal of the feed bend has made possible effective entrainment without choking through a bend of 2ft radius, compared with a 4ft radius, when the feed bend was fitted. Also there was no evidence of damage to the weed at radii of suction bend above 3ft, compared with 4ft, in the previous arrangement. The only differences in the conditions between these and the closed feed suction bend tests were: (*a*) a 5ft instead of a 7ft delivery lift, and (*b*) a total length of entrainment system of 19ft instead of 23ft. It is hardly likely therefore that the improvement in entrainment could be due, in the main, to anything other than the removal of the feed bend. This is substantiated by visual observations of the position of chokages in the closed feed tests.

TABLE VIII—*Effect of Radius of Suction Bend on Choking with an Open Feed System*
Nozzle setting 3 ($A = 1 \cdot 92$in^2), $P_g = 40$ lb/in^2, $Q = 385$ g.p.m., $h_s = 1$ft, $h_d = 5$ft, average size of plant 4ft=stipe, 1ft 6in frond

Radius of bend R_s, feet	Frond or stipe first	Entrainment		Radius of bend R_s, feet	Frond or stipe first	Entrainment	
		No. of plants	Time, seconds			No. of plants	Time, seconds
5	Frond	1	4	3	Frond	1	7
5	Frond	1	5	3	Frond	1	7
5	Frond	1	4	3	Frond	2	8
5	Frond	1	7	3	Frond	3	7
5	Frond	2	8	3	Frond	3	12
5	Frond	3	10	2	Frond	1	28
4	Frond	1	6	2	Frond	1	7
4	Frond	1	5	2	Frond	1	*
4	Frond	1	4	2	Frond	1	14
4	Frond	2	7	2	Frond	1	21
4	Frond	3	6	2	Frond	2	*
4	Frond	3	9	2	Frond	2	25
3	Frond	1	4	2	Frond	2	*

* Choke.

TABLE IX—*Entrainment Times with Open Feed System and Shallow Suction: Plants Presented at Distances Shown from Suction Inlet*
$h_s = 1$ft, $h_d = 5$ft, $R_s = 3$ft 6in

Nozzle setting 1 ($A = 1 \cdot 68$in^2) $P_g = 40$ lb/in^2 $Q = 340$ g.p.m. $Q_s = 590$ g.p.m.				Nozzle setting 3 ($A = 1 \cdot 92$in^2) $P_g = 40$ lb/in^2 $Q = 385$ g.p.m. $Q_s = 660$ g.p.m.				Nozzle setting 5 ($A = 2 \cdot 16$in^2) $P_g = 35$ lb/in^2 $Q = 395$ g.p.m. $Q_s = 610$ g.p.m.			
Frond or stipe first	Distance from suction, inches	Entrainment		Frond or stipe first	Distance from suction, inches	Entrainment		Frond or stipe first	Distance from suction, inches	Entrainment	
		No. of plants	Time, seconds			No. of plants	Time, seconds			No. of plants	Time, seconds
Stipe ...	3	1	*	Stipe	3	1	26	Stipe	3	1	*
Stipe ...	6	1	*	Frond	6	1	8	Frond	6	1	8
Stipe ...	6	1	*	Frond	6	1	16	Frond	6	1	23
Frond ...	6	1	9	Frond	6	1	7	Stipe	6	1	*
Frond ...	6	1	8	Frond	6	1	8	Frond	6	1	19
Frond ...	6	1	7	Frond	6	1	7	Frond	9	1	7
Frond ...	9	1	8	Frond	6	1	10	Frond	9	1	10
Frond ...	9	1	8	Frond	9	1	5	Frond	9	1	6
Frond ...	9	1	10	Frond	9	1	4	Frond	9	1	5
Frond ...	9	1	9	Frond	9	1	7	Frond	9	1	9
Frond ...	9	1	*	Frond	9	1	10	Frond	9	1	6
Frond ...	9	1	10	Frond	9	1	8	Frond	9	1	8
Frond ...	9	1	9	Stipe	9	1	*	Frond	9	1	11
Frond ...	9	1	7	Frond	9	1	3	Frond	9	1	8
Frond ...	9	1	10	Frond	9	1	5	Frond	9	2	10
Frond ...	9	1	12	Frond	12	2	9	S and F	9	2	10
Frond ...	9	2	*	Frond	12	3	20	Frond	9	3	18
Frond ...	9	3	18	Frond	12	3	15	Frond	12	1	13
Frond ...	9	4	35	3 F	12	4	23	Frond	12	2	15
Frond ...	9	3	22	1 S				F and S	12	3	10
Frond ...	12	1	7	Frond	12	4	15	F and S	12	4	12
Frond ...	12	2	10	3 F	12	5	40	Frond	12	5	14
Frond ...	12	2	*	2 S							
—	—	—	—	Frond	12	5	30	—	—	—	—

* Not induced.

(ii) *Entry of Plants to the Entrainment System.*—The object of these tests was primarily to assess the behaviour of plants when presented at various distances from the suction entry, and to obtain further information on entrainment at different nozzle settings.

In the first series, using the basket (Fig. 3) at a depth of about 4ft below the water surface, the pump was operated as before, with a 1ft suction lift and a 5ft delivery lift. Tests were conducted at three different nozzle settings, 1 ($A = 1 \cdot 68$ square inch), 3 ($A = 1 \cdot 92$ square inch) and 5 ($A = 2 \cdot 16$ square inch), with activating water at a pressure of 40 lb per square inch in settings 1 and 3, and 35 lb per square inch in setting 5. The radius of the suction bend was 3ft 6in and the total length of the entrainment system about 19ft.

The behaviour of plants at inlet to and discharge from the system, the distances from the suction entrance at which they commenced to move towards it, and the entrainment times, were carefully noted and recorded.

Very early in the tests it became evident that the plants are less readily induced to enter the suction when they are presented stipe first than when presented frond first. It may be seen from the results, given in Table IX that in six out of twelve runs with the stipe first the plants failed to enter the suction, compared with three out of fifty-five with the frond first.

There appeared to be little, if any, difference in the ease of entry of the plants to the suction pipe or in the total entrainment times at the three nozzle settings. In general, as soon as the frond came within the range of influence of the water flow into the suction the plant was rapidly drawn into the system.

It may also be seen that plants were induced to enter the suction from as far away as 12in, although they were on several occasions assisted by the movement of other plants which had originally settled nearer to the suction inlet. It seems certain, however, that, under the conditions prevailing during the tests, all plants approaching the suction frond first will be induced to enter from a distance of 9in away.

Throughout the tests there was no evidence of draping over the suction entrance or choking of the system, nor of appreciable damage to plants.

Having established at shallow depth that entrainment of whole plants with an open suction was technically feasible, the depth was increased to about 3 fathoms below the water surface, and a second series of tests run at nozzle setting 3. The total length of the system was now about 31ft. The suction and delivery lifts and the activating water supply pressure were, as in the previous tests, 1ft, 5ft and 40 lb per square inch respectively. The radius of suction bend was about 4ft.

This arrangement introduced difficulties to the feed system in that using the previous method of gravity feeding it was impossible at the greater depth to be sure of the instant at which the plants entered the suction pipe. For this reason a new feed system was devised, consisting of a heavy plate, attached to a graduated chain, to force the plants down the wood feed pipe. The commencement of entrainment was assumed to be when the chain became taut at $2\frac{1}{2}$ fathoms.

The maximum distance from the suction inlet at which any plant could emerge from the feed pipe into the basket was about 12in.

The velocities of flow in the suction, discharge and activating water supply pipelines were:—

	ft/sec
Suction	15·9
Discharge	14·2
Activating water	20·8

The results, tabulated in Table X, show that all but one of twenty-five plants were

induced to enter the suction, and were successfully entrained through the system. The one exception was a plant presented stipe first. On the other hand, as many as four, five and six plants presented in groups with one or more in each group arranged stipe first were successfully entrained, although the somewhat high entrainment times suggest temporary choking or sluggish movement through the system.

TABLE X.—*Entrainment Tests with Open Feed System and Deep Suction—Plants Presented Within 1ft of Inlet to Pump Suction.*
Nozzle setting 3 ($A = 1 \cdot 92$ in^2).
$P_g = 40$ lb/in^2, $h_s = 1$ft, $h_d = 5$ft, $L = 31$ft.

Frond or stipe first	Entrainment		Frond or stipe first	Entrainment	
	No. of plants	Time, sec		No. of plants	Time, sec
Frond ...	1	10	Frond ...	1	29
Frond ...	1	12	Frond ...	1	11
Frond ...	1	10	Frond ...	1	14
Frond ...	1	14	Frond ...	1	18
Frond ...	1	28	Frond ...	1	12
Frond ...	1	15	Frond ...	1	14
Frond ...	1	12	Frond ...	2	25
Stipe ...	1	*	Frond ...	2	22
Frond ...	1	25	S and F	2	18
Frond ...	1	20	Frond ...	3	36
S & F ...	2	60	1S & 3F	4	33
Frond ...	1	18	2S & 3F	5	25
—	—	—	2S & 4F	6	26

* Not induced

Capacity of System

The investigations described in this report were primarily to determine the technical feasibility of the high-velocity water jet pump as a means of entraining whole seaweed plants, but several tests were conducted towards the end of the investigation to obtain an indication of capacity.

In the first of the tests the equipment was arranged as shown diagrammatically in Fig. 3, except that the wood feed pipe G and the steel mesh basket J were removed to allow direct access to the bell-mouthed inlet to the pump suction; h_s and h_d, and the pressure of the activating water, were again kept constant at 1ft, 5ft and 40 lb per square inch respectively. The radius of the suction bend R_s was 3ft 6in and the total length of the system was about 19ft.

Typical plants, about 4ft stipe and 1ft 6in frond, were fed to a point approximately 9in from the entrance to the bell-mouthed fitting, at as high a rate as hand feeding would permit, in the following random order :—

(1) Three singles in succession
(2) Two together
(3) Four singles in succession
(4) Two together
(5) Two together
(6) Two singles in succession
(7) Three together
(8) Two singles in succession

All twenty plants were successfully induced into the suction stream and entrained through the system smoothly and without damage. The overall time was twenty-two seconds, and since the total weight was about 93 lb, this represented an entrainment rate of about 6·75 tons per hour.

The test was repeated under similar conditions, except that the depth of the suction inlet below the water surface was reduced to 2ft 6in, thereby reducing also the radius of the suction bend R_s. All the plants were again effectively and successfully induced and entrained, the total time being reduced by three seconds to nineteen seconds and the entrainment rate consequently being increased to about 7·8 tons per hour.

The limiting factor was quite obviously the rate at which two men could feed the system and to facilitate this operation the pump and discharge pipe were inclined at an angle of 45 deg. (Fig. 4), all other conditions being as before. With this arrangement and by making a considerable effort, the operatives were able to feed sixty-six plants, in the following random order, in one minute.

(1) Five singles in succession
(2) Two together
(3) Two singles in succession
(4) Three together
(5) Two together
(6) Seven singles in succession
(7) Two together
(8) Two singles in succession
(9) Four together
(10) Two together
(11) Five together
(12) Three singles in succession
(13) Two together
(14) Six singles in succession
(15) Five together
(16) Two singles in succession
(17) Three together
(18) Four singles in succession
(19) Three together
(20) Two singles in succession

Again all the plants were effectively induced and entrained smoothly and without damage, and it was quite obvious that the maximum capacity had not yet been reached.

The total weight of the sixty-six plants was about 307 lb, giving an approximate entrainment rate of 8·25 tons per hour.

At this rate the proportion of weed in the weed-water mixture pumped through the suction pipe would be as follows :—

Weed entrained = 307 lb/min = 0·074 cu ft/sec.
Pumping rate (approx.) = 660 g.p.m. = 1·76 cu ft/sec.
Proportion of weed in weed/water suction mixture = $0 \cdot 074 \times 100 / 1 \cdot 76 = 4 \cdot 2$ per cent.

This fraction would be reduced in the discharge pipe by the addition of approximately 384 g.p.m. of activating water, the relevant figures being :—

Weed entrained = 307 lb/min = 0·074 cu ft/sec.
Pumping rate (approximate) = 1044 g.p.m. = 2·78 cu ft/sec.
Proportion of weed in weed/water discharge mixture = $0 \cdot 074 \times 100 / 2 \cdot 78 = 2 \cdot 66$ per cent.

Without further investigation it is not possible to say whether or not these ratios are anywhere near the maximum for effective entrainment. The indications were, however, that the system could easily deal with a higher proportion of weed than was possible in the tests using the manual feeding arrangement.

The velocities of flow in the suction and delivery pipes and the activating water supply pipe, during the preceding capacity tests, were approximately :—

	ft/sec
Suction	15·9
Discharge	14·2
Activating water	20·8

Finally, the system was tested by feeding plants continuously for a total period of three hours. The conditions were the same as in the preceding capacity tests except that a fresh batch of plants was used which were found to be of slightly larger average size than those in the previous batch and to have a greater proportion of stipe.

The plants were presented frond first in random order up to a maximum of five together and were entrained at a rate of 4·5 tons per hour for a period of two hours. The feed rate was then stepped up to just over 5 tons per hour and maintained at this rate for a period of one hour.

There was no evidence of choking or stoppage of any kind and entrainment was swift and positive.

Due mainly to the rough handling at inlet in an effort to maintain the high rate of feed, the frond of several plants was torn off, but in spite of this they were all induced to enter the suction and were successfully entrained through the system.

The lower feed rate of 4·5–5·0 tons per hour during these tests compared with the rate of 8·25 tons per hour previously obtained in a test of one-minute duration, is, of course, attributable to the physical limitations of the operatives who had in the later tests to maintain the feed rate over a considerable period of time (three hours). It was quite obvious that this rate was nowhere near the maximum capacity of the system.

Discussion of Results

These investigations have shown that the application of the modified form of high velocity water jet pump to the entrainment of whole seaweed plants without damage is a technical feasibility.

The main disadvantage is the low efficiency of the pump. The efficiency of a conventional centre jet pump is limited to about 25 per cent by the shock loss during mixing of the activating and suction waters and, to a lesser extent, by losses due to wall friction. In the modified form of pump in which the centre jet has been eliminated to provide an obstruction-free access, these losses are greater because of the quicker transfer of energy, or greater shock loss, between the two waters and increased wall friction due to the distribution of the activating water jet into a comparatively thin annulus around the walls of the mixing chamber. In these circumstances the maximum efficiency of about 15 per cent recorded during the tests appears to be somewhere near the maximum that can be expected from the modified form of pump, although some improvement should result from placing the pump at delivery level. Because of the difference in level between the jetty and the water surface it was not possible to test the pump actually in this location except by operating with a suction lift considerably in excess of the actual, which is defined by the freeboard of the harvesting boat, but sufficient variation in delivery lift within a given total lift was possible to give clear confirmation of the trend.

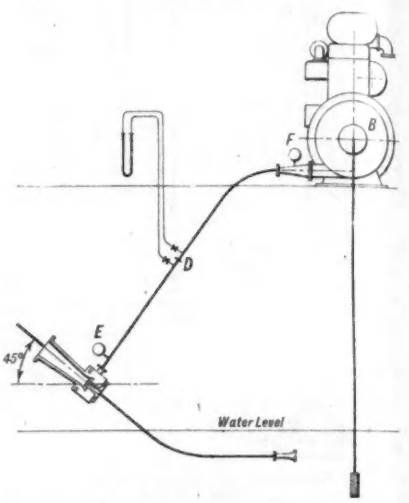


FIG. 4—DIAGRAM OF EQUIPMENT FOR HAND FEED TESTS

One of the principal difficulties in the design of a harvester for sub littoral seaweed is the provision of the necessary high degree of flexibility and manœuvrability to permit operation close to a rocky and, more often than not, treacherous coastline. Placing the pump at delivery level, by reducing the area of that part of the gear which is submerged and therefore subjected to water pressure, has a considerable beneficial effect on these two factors. Other important practical advantages of this arrangement are that it reduces to a minimum the length of the activating water supply pipe and consequently the pressure drop, and facilitates work on the pump in-situ.

In the pumping of solids in suspension in a liquid the form of the suction intake is

known to influence materially the amount of solid matter entering the system. This is particularly true when the solids are of the dimensions of whole seaweed plants. In addition the tests have indicated that without some form of lead-in to guide the tips of the plants to a point where the flow of suction water takes over, most of them are unlikely to enter the intake.

It will be appreciated that the essential difference between the test conditions and actual harvesting conditions lies in the fact that in the latter the entrainment system would be moving forward with the harvesting boat, thereby giving a relative velocity of water flow past the suction inlet, of possibly 3·5ft to 5·0ft per second. Quite obviously therefore, the data obtained during the tests on the behaviour of plants adjacent to the suction inlet must be treated with reserve, and the need for mechanical or hydraulic assistance in concentrating the cut weed at the appropriate place for entrainment assumes greater importance. The form that the lead-in should take and the amount of assistance necessary is possibly the principal outstanding problem in the application of this system to seaweed harvesting.

In spite of the limitations mentioned above, the results of the tests were encouraging; the plants were successfully induced into the suction intake from a distance of 9in and, on occasions, 12in away with a velocity of flow as low as about 9·5ft per second in some cases. It appeared also that plants further away were, to some extent, assisted towards the intake by those which had originally landed closer. The actual entrainment was accomplished successfully and without damage and provided the plants were presented frond first without choking.

The principal factor in choking appeared to be the radius of the suction bend, and it was shown that with a 4½in diameter pipe the size which will be used in the first complete prototype unit, activating water at 40 lb per square inch, and the pump operating with a 1ft suction lift against a 5ft delivery lift, the minimum radius at which entrainment of whole plants can be effected without choking at the bend and without inflicting damage on the weed is 3ft.

One of the *L. cloustoni* plants was found to have several epiphytic growths from its stipe and the resulting "spread" of the upper part of the combined growths was too great to permit entry to the suction inlet. The force exerted by the inward flow of water was quite inadequate to overcome the resistance of the stipes to bending, and it appeared, therefore, to be impossible to reduce this "spread" without cutting to a magnitude at which entry could be effected. Even if this problem could be solved without cutting, it is fairly certain that the pressure exerted on the suction pipe walls due to the resilience of the weed would, in any case, prevent effective entrainment.

In such cases it would therefore be necessary to adopt some means of clearing the offending plant from the vicinity of the suction inlet. Possibly the simplest device for this purpose would be a branch pipe from the activating water supply line connected to the suction pipe just below the jet pump, which, with a suitable arrangement of valves, could be used to pump water down the suction pipe and out of the suction inlet. Since the head against which this water would be pumped is considerably less than when pumping through the nozzle of the jet pump, a considerably increased flow will result, which should effectively clear obstructions at the intake to the system without the need for raising and/or dismantling the equipment.

A series of tests run to enable an assessment to be made of the capacity of the system showed that, under the test conditions, it was capable of handling whole plants at a rate of 8·25 tons per hour, although it was physically impossible to maintain this rate of feed for longer than one minute with hand feeding by two men. Rates of 4·5 tons per hour and just over 5 tons per hour were, however, maintained for two hours and one hour respectively without any evidence of choking or stoppage of any kind. In all these capacity tests the plants were fed frond first and in random order, to simulate actual harvesting conditions as nearly as possible.

ACKNOWLEDGMENTS

The valuable advice and assistance given by Mr. J. Young, M.I.Mech.E., and Mr. C. H. Carslaw, of Drysdale and Co., Ltd., Glasgow, and the use of the jetty and equipment belonging to Mr. P. Boyle, of Timbacraft Ltd., Shandon, are acknowledged.

The work described in this article forms part of the programme of research and development on seaweed undertaken by the Institute of Seaweed Research to whom the authors are indebted for permission to publish.

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Technical Committees

(Contributed)

ALTHOUGH technical committees differ from ordinary committees in that they are only existing for sound technical reasons, I cannot honestly say that I have enjoyed my attendance at such committees more than at non-technical ones. Logically, this is odd, and perhaps members of committees do not always fully realise the possibility of this kind of work.

A technical committee exists in order to make decisions or rules which are based on a wider range of facts than any one member could be expected to know, and which are reached by more consistent reasoning than a normal individual would maintain.

The great advantage which a technical committee may be expected to have is that it exists to make reasonable deductions from ascertainable facts; this makes its work much easier than that of the committee of a political organisation, or a music club, or a publicity drive, or even of a Church.

Some light on the nature of committees may be gained by looking at the mock-definitions which are often produced; thus, for example: "A committee is an organisation to share the responsibility of avoiding difficult decisions" sums up one of the worst failings which a technical committee can reach.

A committee may be hampered by a poor chairman, and the election of a chairman should be slowly considered by any technical committee; a series of temporary chairmen may well be tried in order to find a preferred personality. First, one must avoid the trap of putting the most knowledgeable member of the committee in the chair; wisdom, rather than knowledge, is required, and the measure of humility desirable in a chairman is rarely reached by an expert. Knowledge of people being more important in a chairman than knowledge of things, it often happens that a good chairman is chosen by a majority vote of the members. This is a less reliable guide in the choice of a good secretary, since the blend of efficiency, tact and skill, necessary for a secretary is more difficult to recognise than wisdom. Consequently, there is something to be said for appointing two or three members of the committee to look for, and then nominate, a secretary. When he is elected, he must study the membership of the committee, and especially the chairman, with even more care than he studies his minutes, for it is to be expected that the minutes deal with a subject he already knows. If he wishes to guide the whole committee, he must learn to do so anonymously, through the chairman; and to give the impression of self-effacement.

One of his most subtle tasks is the preparation of each agenda. This should contain enough facts to make it clear to the member that the next meeting will be an important one, and also, like a circus programme, it should arouse expectation in the reader. It is essential to avoid giving the impression that the committee has been called to endorse a series of decisions which have already been made. Minutes also require skilled drafting, and it is often wise to submit a draft minute for approval by a meeting before it breaks up, rather than to risk circulating a minute which inadequately represents what has been discussed.

From the rest of its membership a successful committee requires chiefly persistence and faith, the sort of faith in the collective wisdom of its members which is illustrated by the following passage relating to a report. The persons who compiled the report were two business men, a chemist, a physicist and a government administrator, and the subject of their study was novel and important. One of them is reported to have said:—

"At the very first meeting, the group agreed the subject was too important to be subject to the hazards of the push-and-pull of the committee approach. And so, even before we studied the problem, we studied committee techniques.

"It seemed to be fairly well agreed that most committees break down because many members come to their job with fully-formed conclusions, having almost property rights in their own ideas, and spend all their time proposing and exhorting rather than listening and considering.

"Our first joint decision, then, was to liberate all our discussions from idea-possessiveness. No point would be argued down; we agreed that we would attack the problem inductively, working from the ground up, assembling all facts pertinent to the problem as a basis for conclusions, implied or implicit. We agreed that all questions coming up were to be considered as being brought up by the group as a whole rather than by any single member. If a member had an objection to any one point, it was to be regarded as something that troubled the group as a whole.

"We agreed, too, that we were not going to issue a watered-down report just for the sake of coming out with a report. We were not going to get into the usual type of barter system, trading off one pet idea against another, getting into committee 'deals' just for the sake of carrying off individual honours. We agreed that we would issue five reports if any of us felt that the group report lacked directness and honesty.

"You might call this a sort of search for individual and group objectivity. At the least, it meant that each of us was pledged to attempt to emancipate himself from the tyranny of his own ego. We were trying to create a collective wisdom."

The committee in this case was the Lilienthal - Acheson Committee, producing their 1946 Report on the International Control of Atomic Energy.

The Royal Show at Newton Abbot

No. III—*(Concluded from page 13, July 4th)*

THE annual show of the Royal Agricultural Society of England was held at Newton Abbot, Devon, last week, and by the time it closed on Friday evening had been visited in four days by just over 91,000 people, compared with an attendance at Cambridge last year of 131,333. By far the largest attendance last week was on Wednesday on which day the Show was honoured by a visit of Her Majesty The Queen. The occasion was historic, it being the first time for over 300 years that a reigning Monarch has paid an official visit to Newton Abbot. Her Majesty spent several hours at the Show.

Although the 117-acre site on which the Show was staged was in many respects less convenient to "organise" than other sites occupied by the "Royal" in the post-war years, visitors found the result of the Society's efforts just as attractive as always—despite the rather long walk from the car parks to the entrances! The arrangements throughout were the responsibility of the honorary director, Mr. Michael Mason, who was ably assisted by Mr. Alec Hobson, secretary of the Royal Agricultural Society, and his staff.

Silver Medal Awards

Nine implements—including three deferred from the 1951 Show—were accepted for final judging for the Royal Agricultural Society's silver medal awards. The medals are awarded for machines "which fulfil a purpose of value to agriculture for which no machine has hitherto existed, or, if the purpose is not new, which embodies some new principle of working." The implements were judged by Mr. Roland Dudley, A.M.I.C.E., Mr. A. Herbert Carter and Major T. K. Jeans, who recommended the award of medals to Ernest Doe and Sons, Ltd., Ulting, Essex, for a silage and green crop combine; Simplex Dairy Equipment Company, Ltd., Cambridge, for the "Downham-Simplex" animal sprayer, and Ransomes, Sims and Jefferies, Ltd., Ipswich, for a mounted reversible plough.

The machine entered by Ernest Doe and Sons, Ltd., was also awarded the Burke Perpetual Challenge Trophy. This machine—which is known as the "T–D" silage combine—is self-propelled, and was designed by Mr. R. G. Tayler, of Strutt and Parker (Farms), Ltd., in co-operation with Massey-Harris, Ltd., and Ernest Doe and Sons, Ltd. It is based on the chassis of the Massey-Harris "726" combine-harvester, which has a cutting width of 8ft 6in, the cut crop being collected by the pick-up reel and passed to an elevator which conveys it to a trailer attached to the rear. Power is provided by an Austin six-cylinder petrol engine, and although small alterations to the standard cutter-bar and certain parts of the operating mechanism have been made, there is no difficulty over converting the silage combine back to a grain combine. As the machine hauls the loading trailer, a tractor is not required except for towing away the full trailer and returning the "empties."

"Devon Reports Progress"

A particularly interesting part of the Royal Show—especially to engineers—was the section aptly entitled "Devon Reports Progress," which occupied much of the space allotted originally to the cattle exhibits. When the decision had to be taken to abandon the "cloven-hoofed" section, on account of foot and mouth disease, there was little time prior to the opening of the Show to make arrangements for suitable displays to take its place. Nevertheless, the result of the efforts made immediately by the Royal Agricultural Society, other interested organisations, established machinery exhibitors, and local engineering firms is worthy of high commendation. Over thirty firms with works in Devonshire contributed to a comprehensive display showing the county's post-war engineering achievements, with special emphasis on agricultural and forestry machinery. This display was organised in a fortnight, chiefly through the energies of Mr. W. P. Authers and Mr. T. A. Stodart, joint managing directors of E. V. Twose, Ltd., and Stenners, Ltd., Tiverton. At intervals during each day of the Show there were working demonstrations of mounted implements manufactured in Devonshire, which were accompanied by explanatory running commentaries broadcast by Mr. Stodart. In addition to agricultural implements, the Devon firms' display included food preparation machinery, electrical measuring instruments, electric control equipment, hand tools, small yachts and boats, a three-wheeled 2½ h.p. motor car, neon signs, a "Skyjeep" single-engined high-wing aircraft, examples of structural engineering and wrought ironwork, a display showing the activities of the North Devon Water Board, and a selection of the castings produced at the Exeter foundry of Garton and King, Ltd. "Devon Reports Progress" was certainly indicative of the valuable contribution being made to the work of the engineering industry by the smaller firms established within the county.

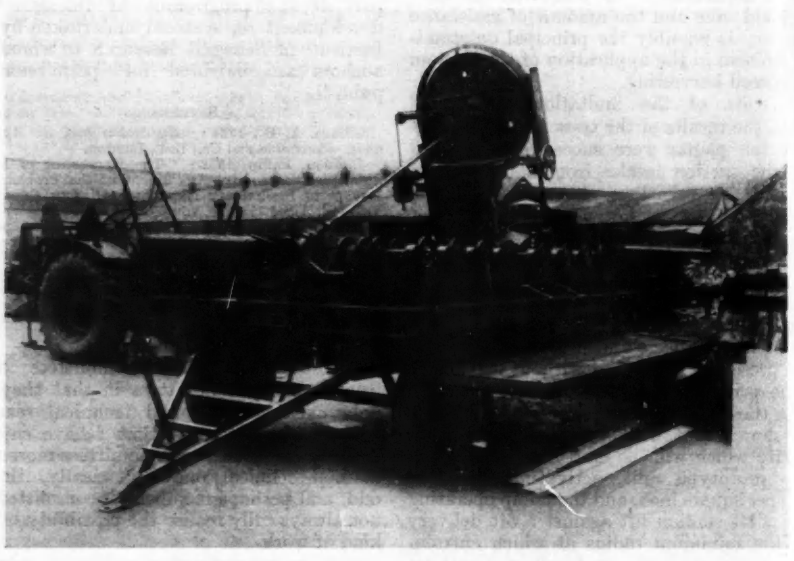

FIG. 13—TRANSPORTABLE BANDSAW—STENNERS

To this impressive display, Stenners, Ltd., Tiverton, contributed a replica of a modern joinery shop equipped with the various woodworking machines which it manufactures. These machines were to be seen at work on the production of wheelbarrows, gates, fencing, and other items of farm and garden equipment. Adjacent to the joinery shop, a transportable band saw, which has recently been designed by Stenners, Ltd., and which is illustrated in Fig. 13, was at work. This outfit comprises a 42in band saw, fitted with roller tables 10ft long, with two head blocks, and mounted on a road trailer for haulage by tractor to the site where it is required to work. The machine portion of the equipment has a substantial column and baseplate which carry the top and bottom pulley assemblies, the top pulley being adjustable on slideways for saws of various lengths. Both the top and bottom saw pulleys are mounted on heavy spindles which are carried by spherical roller bearings in dustproof housings. The 10ft long steel tables, which are 18in and 10in wide, are fitted with steel guide rails and bearer bars, and ball-bearing-mounted rollers give free running during heavy cuts. The two head blocks, which have gripping dogs to hold the logs, are connected by a set shaft, the movement to and from the saw being lever controlled. These head blocks can be quickly removed to leave the tables clear for resawing or squaring. A feed gear, which takes the drive through reduction gearing to the tables, gives variable forward and quick-acting return speeds. The drive has been arranged to suit agricultural tractors, a pulley for flat belt being fitted to the bottom saw pulley and a deflector pulley being provided on the chassis.

The chassis, which has been designed to form part of the main members of the table framework, is mounted on four pneumatic-tyred wheels, the rear wheels being fitted with brakes. The main pulley unit of the bandsaw is hinged on the chassis, the arrangement allowing the bottom pulley to swing upwards to give adequate ground clearance. For setting up the machine on uneven ground, screw jacks are fitted, one at each corner of the chassis and two in the middle; when in transit the jacks are swung under the chassis. The operators' platform is placed at the side of the machine and is detachable for the transit of the equipment.

In the remainder of this article we conclude our description of a selection of the machines and implements shown on some of the machinery stands.

M. B. Wild and Co., Ltd.

The selection of implements shown by M. B. Wild and Co., Ltd., 50, Pall Mall, London, S.W.1, included a small tractor mounted forage harvester, which cuts and chops a crop, and a mechanical spreader for disintegrating and distributing farmyard manure which has been laid out in rows or heaps in a field. A rear view of this latter implement is shown in Fig. 14. The implement is hauled by a tractor and driven from the power take-off. It consists of a welded steel frame which is mounted on two land wheels, and which carries two drums—one for collecting and shredding and the other for spreading the manure. The squirrel-cage collecting and shredding drum comprises a steel shaft, carried on self-aligning bearings, on which are mounted the steel discs supporting the collector bars and their welded-on shredding fingers. The spreading drum, which is of fabricated steel, is also carried on self-aligning bearings. As may be noted in our illustration, it has a left and right-hand spreader screw, which has been designed to give a broad and even distribution of the shredded manure. The main drive from the tractor power take-off is through a universal joint to a telescopic shaft, which shaft is coupled to the gearbox on the right-hand side of the machine through another universal joint. The gearbox, which is

totally enclosed, transmits the drive to the spreading drum shaft by machine-cut bevel gears running in oil, the shredding drum being driven from the spreading drum by an enclosed roller chain drive on the left-hand side of the machine. The steel land wheels have staggered

FIG. 14—MUCK SPREADER—WILD

spokes and their spindles are carried on cranked arms which provide height adjustment for the shredding drum. The overall length of the machine is 8ft and its overall width is 5ft 10in. Its width of spread is approximately 15ft.

SALOPIAN ENGINEERS, LTD.

In the land reclamation schemes which are now in progress in many parts of the world the disc plough is proving itself a particularly useful implement and a number of such ploughs could be seen on several stands at the Royal Show. An example of the disc ploughs built by Salopian Engineers, Ltd., Prees, near Whitchurch, Salop, is illustrated in Fig. 15. It is one of the firm's "Classic" series of ploughs and is a strongly constructed implement, with the main beam built from high-grade 3in square bar steel. The plough is equipped with heat-treated carbon steel discs, which can be of 26in, 28in or 30in diameter and are dished to a special

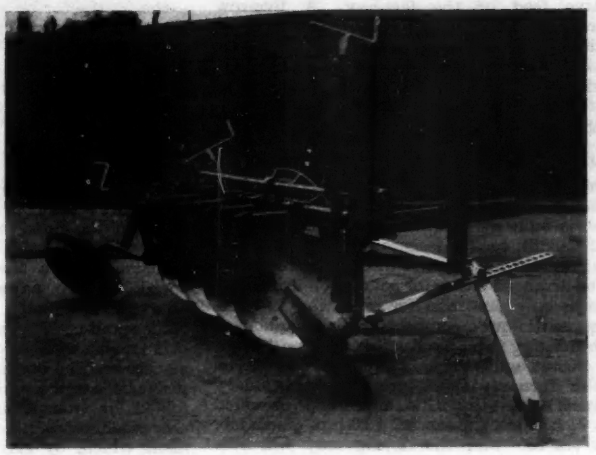

FIG. 15—DISC PLOUGH—SALOPIAN

furrow wheels to assist penetration in very hard soils. The plough is a tractor-mounted implement, its webbed land wheel having been designed to assist a positive self-lift. The ploughing depth can be adjusted by a telescopic screw device on the land wheel assembly, and disc levelling is effected by a screw crank acting on the front of the plough and on the rear furrow wheel assembly.

DENINGS OF CHARD, LTD.

Among the West Country agricultural engineering firms exhibiting at Newton Abbot was Denings of Chard, Ltd., Chard, Somerset, which produces a variety of implements including drills, harrows, potato spinners, mowers, hay rakes and balers. Among its haymaking machinery is the "Somerset" power take-off driven semi-mounted mower, a photograph of which is reproduced in Fig. 16. The frame of this mower is a triangulated structure of channel section steel, the forward end of which pivots on the hitch plate which is fixed to the tractor drawbar by a two-bolt attachment. A malleable iron latch, held by an adjustable compression spring, provides a safety release so that the main frame and cutter bar swing back should attached to the wooden connecting-rod by two tempered spring plates. The tilt of the cutter bar is controlled by an adjustable steel rod, enabling a level cut to be maintained irrespective of drawbar height. A hand-controlled tubular lever operates a toggle mechanism having an over-centre lock, which gives a lift to the machine of 10in ground clearance at the inner end of the cutter bar and 20in at the outer. The main drive to the mower from the tractor power take-off is by a Hardy Spicer shaft to a triple vee belt pulley, the belts transferring the drive to the crankshaft pulley. The well-balanced crank wheel is shrouded to prevent haywinding, and the whole of the power take-off assembly is covered by a telescopic safety sleeve. The total weight of the machine—with a 5ft cutter bar—is about 6¼ cwt.

E. ALLMAN AND CO., LTD.

An addition to its spraying machines which was shown for the first time by E. Allman and Co., Ltd., Birdham Road, Chichester, is the "120" universal sprayer for attachment to the Ferguson tractor. The spray booms give an effective spraying width of 18ft 2in and fold back if an obstruction is encountered. The

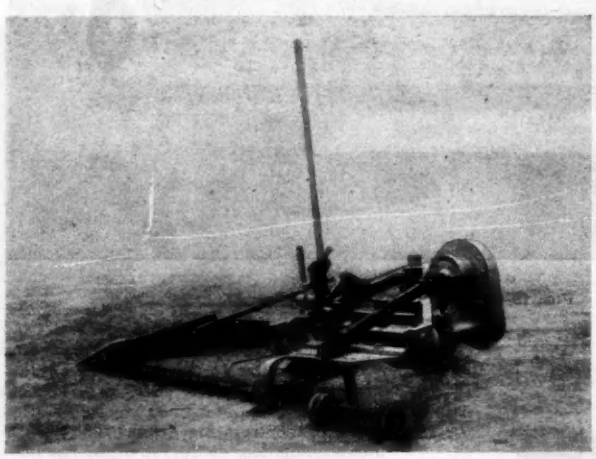

FIG. 16—SEMI-MOUNTED MOWER—DENINGS

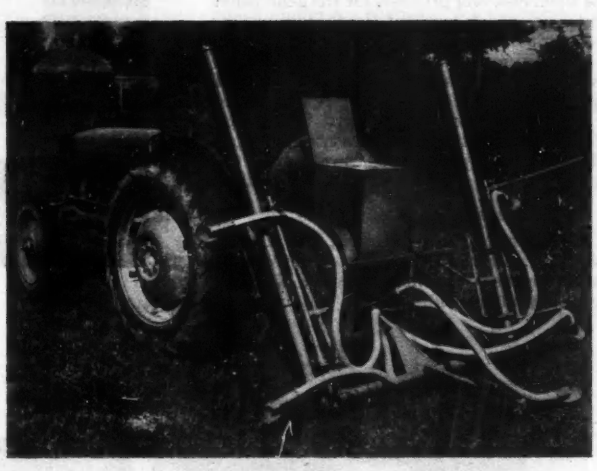

FIG. 17—"PESTMASTER" DUSTER—ALLMAN

radius. The disc saucers have flush-fitting centre spigots, and mounting to the main beam is by high-duty brackets incorporating housings for precision taper roller bearings. The brackets are secured to the main beam by high-tensile U-bolts and are provided with holes to give easy adjustment of the pitch of the disc. The furrow wheels are made of high-duty cast iron and are provided with wide rims to minimise sinking on soft surfaces, and standard wheel weights may be fitted inside or outside the

any obstruction be encountered when mowing. A three-point standing position is obtained by the rear castor wheel and an adjustable built-in wheeled jack at the forward end. The cutter bar assembly—which is available in cutting widths of 5ft, 6ft or 7ft—consists of an alloy steel bar section, with a slight initial camber to ensure a flat working position, and knife clips and fingers of drop-forged steel. The big end bearing is a malleable iron housing containing a two-row rigid ball bearing, and is

sprayer requires three tanks, their total capacity being 120 gallons, one of which is mounted on the hydraulic lift of the tractor, the other two being centrally placed on either side of the tractor. The pump is fitted with phosphor-bronze casing and rotors mounted on stainless steel shafts, its output being 634 gallons an hour at 200 lb per square inch. The recommended speed for operating the sprayer is 4 miles an hour.

Another sprayer exhibited by the firm was the

"Postmaster" duster, which is illustrated in Fig. 17. This is also a tractor-mounted machine with a folding boom 16ft 8in wide. The duster is powered by a four-stroke engine, the drive to the high-duty fan being by vee belt. The powder hopper will take about 112 lb of average fertiliser powder, and an agitator, with its spindles mounted on lead-bronze bushes, ensures positive feed of the fertiliser. A five-row dusting unit, which is carried on the boom, consists of five flexible metallic tubes, which are adjustable for height and row spacing. They are fitted with "spoon" spreaders to ensure that the fertiliser completely envelopes the plants being treated.

Edward Curran Engineering, Ltd.

The crop-drying equipment exhibited included examples of the Slade-Curran drier, which is built by Edward Curran Engineering, Ltd., Cardiff, to the design of Dr. R. E. Slade. It is intended for small or medium-sized farms, can be arranged either for coke or oil firing, and requires only one man for operating it. The equipment is quite compact and can be housed in an existing farm building or under a "lean-to" erected against such a building. It consists of the furnace, spark trap and secondary air inlet, a fan—the drive for which is provided by a 7½ h.p. electric motor, a 10 h.p. oil engine, or a tractor—and the drying tray which is brick-built for use in this country and constructed of steel for the export market. The internal dimensions of the tray are 16ft long, 7ft wide and 2ft 6in deep. Unloading shutters can be fitted at the end or on either side of the tray, and perforated steel sheets form the floor on which the crop is dried. Steel ducts, which connect the furnace to the drying tray, convey the hot air to the underside of the perforated plates, the drying temperature for grass being from 200 deg. to 250 deg. Fah. and for grain 110 deg. to 180 deg. Fah. The illustration, Fig. 18, shows the oil-fired furnace used for the Slade-Curran dryer. It is designed to consume from 6 to 7 gallons of diesel oil an hour, and an air compressor driven from the shaft of the fan supplies compressed air to the burner to atomise the oil and ensure complete combustion. There are two coke-fired models of the dryer, the first being fitted with an open-hearth furnace which needs about ¾ cwt of coke an hour. The second is equipped with a semi-gas producer furnace designed for an hourly coke consumption of 70 lb. The furnace is hopper fed. A water drip to the grate bars keeps them cool and provides for the generation of water-gas which burns at the furnace outlet, a constant temperature being maintained. The makers say that an average output of 1¼ cwt of dried grass an hour can be obtained with this equipment when drying from three to four batches of wilted grass a day. The drying process for each batch takes from two and a half to three hours, depending, of course, upon the moisture content of the material to be treated.

Massey-Harris, Ltd.

A few years ago, Massey-Harris, Ltd., Barton Dock Road, Stretford, Manchester, introduced its self-propelled combine-harvester, No. 726, which has a cutting width of 8½ft. This machine, together with other implements and tractors now manufactured by the firm in this country, was displayed last week. In addition, Massey-Harris, Ltd., exhibited—for the first time—the tractor-drawn No. 750 combine-harvester, which it is putting into production with the requirements of smaller farms particularly in mind. The overall length of the machine (Fig. 20) is 20ft 9in, and its working width10ft 10in, the width of the cutter bar being 5ft 6in. The machine has a two-speed, six-arm adjustable reel, and a three-spout bagging attachment with a rotary screen. The bagging platform can be easily folded for transporting the machine, a refinement which, by giving a transport width of 8ft 6in, helps a great deal when narrow lanes and gateways have to be negotiated. Power for operating the machine is provided by a four-cylinder, side-valve, water-cooled Morris engine, developing 25 b.h.p. at a governed speed of 2220 r.p.m.

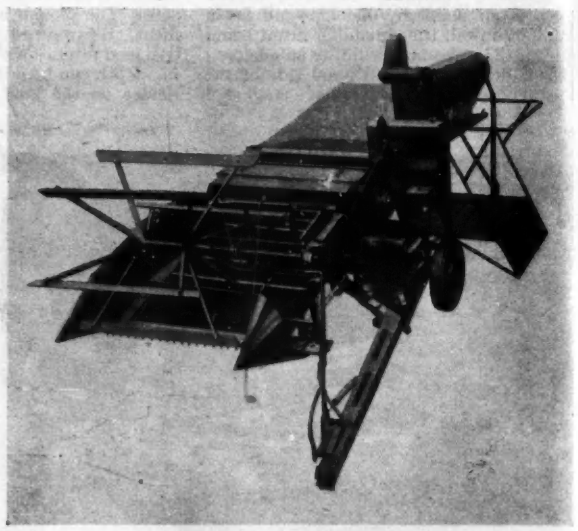

FIG. 20—COMBINE-HARVESTER—MASSEY-HARRIS

Alpema Agricultural Machinery Development Company, Ltd.

A few months ago, the Alpema Agricultural Machinery Development Company, Ltd., Redhill, Surrey, was formed for the production of agricultural machinery designed primarily for use on farms of up to 200 acres. Its exhibit at the Royal Show consisted of the machines which it is now manufacturing, including the "Econolizer" fertiliser placement drill, the "Vedor" seed and dry fertiliser spreader, and a sack and bale elevator which can be adjusted to any height between 7ft and 12ft. Another of the firm's products which was shown is the "T.L." mobile crop dryer, illustrated in Fig. 19. It has an overall length of 27ft, a height of 9ft, and a width of 7ft 6in, and can be conveniently towed by a tractor. The dryer employs a burner similar to those used in aircraft gas turbine engines. The crop is dried between two drums, an outer one, which is stationary, and an inner rotating drum. The crop is fed into a filling door at the top of the machine and is carried by spring-loaded tines between the two drums. Hot air from the burner is drawn by a fan through the centre of the rotating drum and is discharged into a duct running the full length of the fixed outer drum. It then passes through a screen and flows around each side of the rotating drum, drying the crop on its way, before discharging through a screen into the trunking. In the process, a proportion of the saturated air is bled off to atmosphere and the remainder is recirculated with the fresh intake of hot air. The temperature is thermostatically maintained and does not exceed 300 deg. Fah. The average capacity of the dryer is stated to

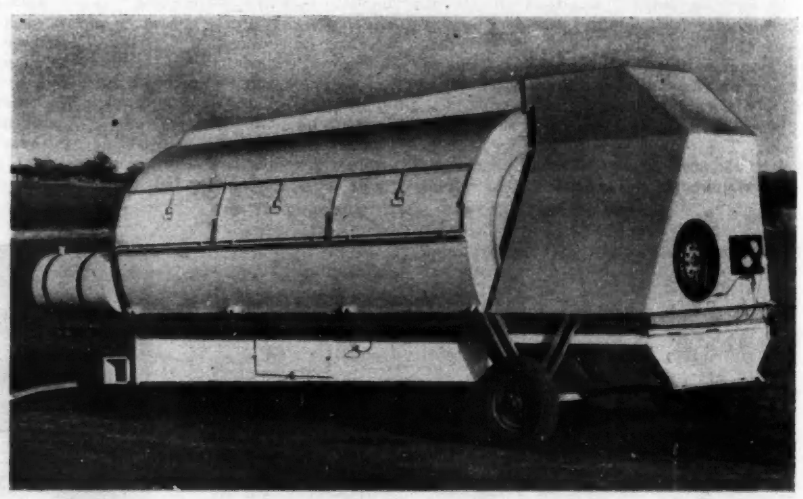

FIG. 19—MOBILE CROP DRYER—ALPEMA

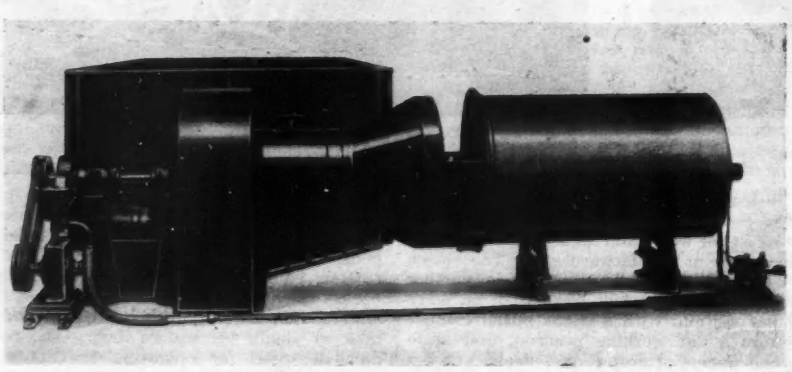

FIG. 18—OIL FIRED FURNACE FOR CROP DRYER—CURRAN

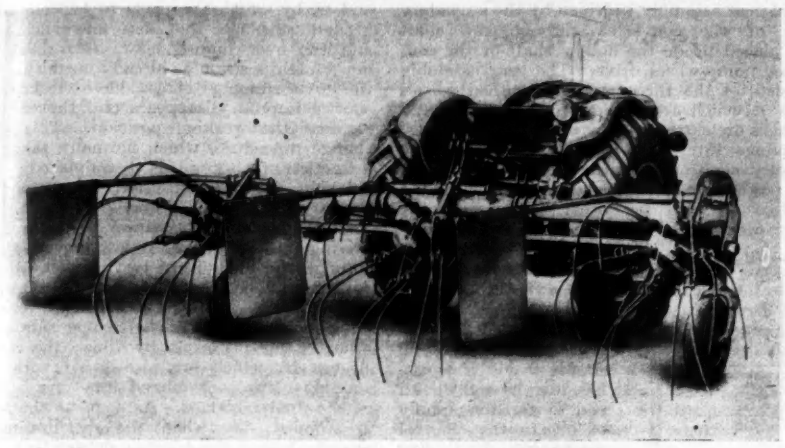

FIG. 21—MOUNTED SWATH TURNER—BAMFORDS

be 3 cwt of dried material an hour, the average fuel consumption per ton of dried output being 60 gallons of vaporising oil or gas oil. The fuel tank of the dryer is of 80 gallons capacity. The power requirement for operating the dryer is 10 h.p., which can be applied from a tractor, stationary engine or self-contained engine mounted on the machine itself. The equipment can be conveniently arranged for grain drying. The Alpema Company is producing the burner and fan unit to form a portable air heater for such purposes as grain drying, greenhouse heating or de-frosting orchards. Its maximum heat output is 200,000 B.Th.U. an hour, and the fan will deliver 5000 cubic feet a minute at pressures up to 2in water gauge. The heater, which is 8ft long, 3ft wide and 5ft high, and weighs 10 cwt, is mounted on two pneumatic-tyred wheels, and can be moved about by one man.

E. V. TWOSE, LTD.

One of the implements entered for the silver medal award was a ditching machine which has been designed and produced by E. V. Twose, Ltd., Lowman Works, Tiverton. This implement was shown on the company's stand, and throughout the week was demonstrated in the "Devon Reports Progress" exhibition referred to earlier in this article. The ditcher, which

FIG. 22—VERGE TRIMMER—TWOSE

has been built for use with tractors equipped with hydraulic lift, is in two parts, both of which fit on to the same tool bar. The first attachment takes out a trench approximately 16in wide and 9in to 10in deep, and the second attachment follows in the same trench, taking it to a depth of about 20in.

Another implement which was exhibited by E. V. Twose, Ltd., is a roadside verge trimmer fitted with a spoil dispersal unit. This implement, a photograph of which is reproduced in Fig. 22, is tractor mounted and consists of a 12in plough beam and body arranged on a fabricated frame so that the plough operates in an offset position. The vertical cut is made by a single arm rolling coulter, the nearside front wheel of the tractor being used as a marker. For the horizontal cut a specially shaped scoop is fitted, together with a spinner arrangement which is driven from the power take-off of the tractor, the result being that the spoil is thrown on to the verge instead of falling back on the road surface. A guard is provided above the spinner to prevent danger from flying stones. In use by a public authority, the trimmer has shown itself capable of cutting and dispersing from 12 to 20 miles of roadside verge in a single working day.

BAMFORDS, LTD.

The tractor-mounted swath turner and windrower illustrated in Fig. 21 was one of the principal exhibits of Bamfords, Ltd., Uttoxeter, Staffs. Its main frame comprises a large diameter single tube, giving a close-up connection with the tractor, and its two pneumatic-tyred castor wheels control the working height. The implement is equipped with three turning heads and can handle three 5ft swaths, the drive for the heads being taken from the tractor power take-off shaft through bevel gearing and a transverse shaft. When swath turning, all the heads rotate in the same direction, the two outer ones being adjustable to allow for slight variations in width of swath. But, when windrowing, the centre head is reversed so that the left-hand and centre heads turn inward to form one windrow, the right-hand head turning outward to form half a windrow and the other half being completed on the return run. On account of its width, the machine is arranged for endwise towing, which is accomplished by the provision of a detachable third wheel. This third wheel is also of assistance when the machine is being mounted on a tractor.

THE 1953 ROYAL SHOW

Next year the Royal Show is to be held at Blackpool from Tuesday to Friday, July 7th to 10th.

The "Mekydro" Hydraulic Transmission

A HYDRAULIC transmission showing advanced conceptions for diesel locomotives and railcars is the Maybach "Mekydro" design now being operated by the German Federal Railway in several 1000 h.p. diesel locomotives after observing behaviour of a trial set in a 600 h.p. power van since the end of 1938.

Actually this drive is on the hydro-mechanical principle in that change-speed gears are allied to a Föttinger turbo torque converter. But both hydraulic and mechanical portions embody ideas not seen before in either of those transmission systems. The unit is illustrated herewith.

In the first place the hydraulic converter is permanently filled, thus, compared with the normal design, which is emptied and refilled at each change of stage, it saves time and a break in tractive effort, and also avoids that decomposition of converter oil which occurs above a certain temperature and is due to the mixing of oil and air at each change of converter stage. Secondly, the turbo converter has been adapted so that the turbine rotor can be displaced axially and act as a disengaging clutch. The necessary synchronising means for gear-changing is thus incorporated in the hydraulic part of the transmission instead of in the mechanical part, so there are no parts subject to wear. It is this characteristic, too, which eliminates the need for a separate turbo converter for each speed stage desired.

Allying a set of change-speed gears to one permanently filled converter means that the converter can be designed to work only in the highest part of its efficiency curve, where it is maintained by the change-speed gears up to top speed. The highest efficiency of turbo converters is now over 80 per cent, but in normal kinds there are steep drops below this until the next converter is engaged. In the

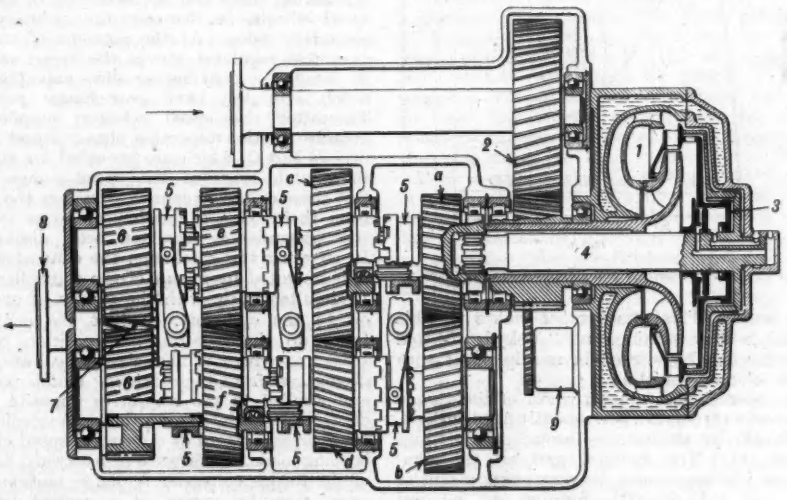

FIG. 1—CONVERTER AND CHANGE SPEED GEARS

"Mekydro" design efficiency rises to 80 per cent at about 20 per cent of the top track speed and it ranges from 80 to 82 per cent from there right up to the top track speed (see Fig. 3). The efficiency rises steeply enough from zero speed for frequent rapid accelerations to be made and full available tractive effort to be transmitted continuously from about 17 per cent of top speed upwards, without any undue oil heating. In practice the converter is surrounded by a cooling jacket piped to the engine water system, and a separate radiator is not required.

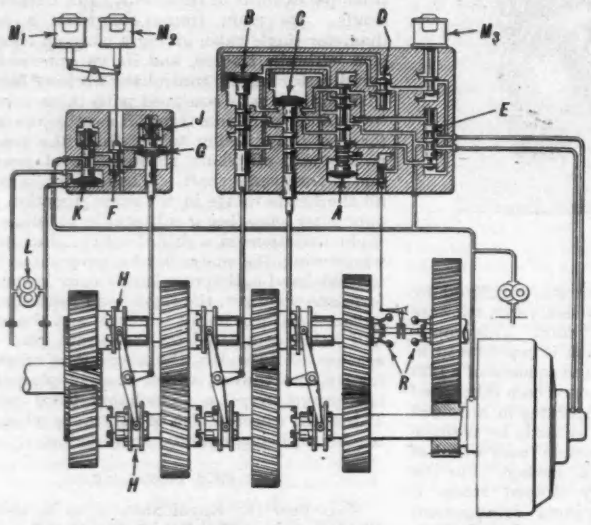

FIG. 2—SPEED AND DIRECTION CONTROL ARRANGEMENT

To make the whole transmission complete it was obvious that a completely automatic gear-change was needed, and this was provided by the development of Maybach's over-running claw clutch into an interlocking claw clutch. There is one of these between each pair of gear-wheels, as can be seen in the illustrations; and they make the change from one set of gears to another—up or down—quite automatically. The driver controls the locomotive or railcar simply by moving a throttle handle, and so varying the engine r.p.m. and by using the brake. This arrangement makes possible multiple-unit working and "Mekydro"-fitted vehicles can be worked in multiple-unit with diesel-electric vehicles.

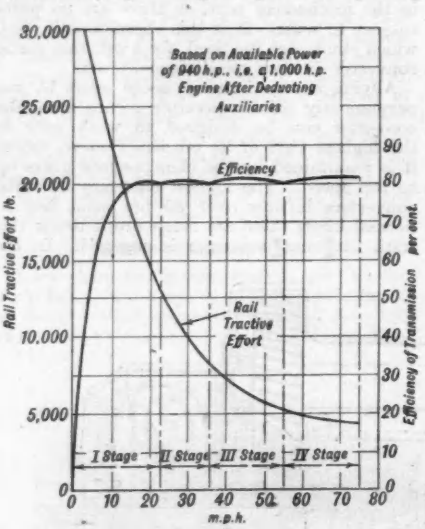

FIG. 3—PERFORMANCE CHARACTERISTICS

In operation the pump wheel of the torque converter (1) (Fig. 1), permanently filled with oil, is driven by the engine through the step-up gears (2). The turbine part of the converter is engaged and disengaged by means of the oil cylinder (3), forming an integral part of the converter. The three-pair, four-speed gear assembly is driven by the secondary part of the converter through the shaft (4), placed inside the hollow shaft of the converter pump-wheel drive. The gear assembly consists of the three pairs of toothed wheels *a* to *f*, which are in constant mesh. Speed changes are carried out by means of the change couplings (5). The reversing gears (6) are directly connected to the transmission gear; the power flow goes through one wheel or the other, according to the direction, to the common driven wheel (7), arranged below; and thence via the flange (8) to the cardan shafts and axle bevels. The gear-type pump (9) shown inside the gear-box to the right-hand end is for the supply of oil to the control mechanism, for feeding the converter, and for the lubrication of the transmission.

A vital element in the whole transmission, the interlocking claw clutches, operate on the principle of a change-speed coupling with inclined faces on the claws. If, for example, the driving shaft sleeve, which carries the two movable parts of the coupling, is taken straight out of its former clutched position, without stopping in an intermediate position, and with the full difference in rotational speed at relatively small pressure applied to the claws of the opposite half of the coupling, then the claws, because of their inclined faces, repulse each other without any clutching action just as long as there is any difference in speed between the driving sleeve and the gearwheel which is to be coupled. Clutching takes place as soon as the relative speed has passed through zero, that is, once the row of claws with the hitherto lower speed begins to overtake the opposite claws. To effect this relative movement, only a deceleration or acceleration of the driving parts is needed.

To these claws has now been added an interlocking clutch ring, arranged concentrically in relation to the clutch ring which transmits the power, and which prevents the inclined engaging faces of the claws touching each other during the repulsion procedure.

Though initiated in its action by the relation of vehicle speed, engine speed and load, the mechanism of the control operates by oil pressure. Referring to Fig. 2, the change-speed regulator *R* is located between the step-up driving gears and the first pair of change-speed wheels, i.e. between the primary and secondary sides. At the moment of change-over this regulator moves the speed selector *A* through a distributing slide valve by one notch into the next gear-change position. Thereafter the speed selector supplies oil pressure to the respective change-speed cylinders *B* and *C*, which are provided for shifting the clutch rings in the speed-change gear. But these cylinders cannot disengage the claws from their existing clutch position as long as the transmission has not been discharged. In effecting this discharge, the converter slide *E* is operated by means of the controller slide *D* simultaneously with the supply of pressure oil to the cylinders, so that the converter takes up the disconnecting position by its axial movement. The claw rings are then disengaged from their existing clutch position and applied to the respective opposite claws of the new clutch position. According to whether an upward or downward speed change is being made, the forward or backward blading of the torque converter is put in motion for a short time by means of a control impulse produced by the piston rods of cylinders *B* and *C*, by which the parts to be coupled are brought through the state of synchronism, and the over-running claws then take their new clutch position as already outlined. Once the over-running claws have locked, the control impulse disappears and the converter resumes the working position. This speed-change procedure, which normally takes only a fraction of a second, is then finished; but a delaying device is inserted to prevent any oscillation round the change-over point.

In the reversing operation the lever in the driving position moves a distributing slide *F* through the medium of two magnets *M*1 and *M*2 mounted on the transmission gear. According to the position of the reversing lever, oil under pressure is applied to one side or the other of the piston *G*, by which the reverser sleeves *H*, which are also fitted with over-running claws, are moved into one or other of the final positions. As soon as the engine is stopped, i.e. when the distributing oil pressure ceases, the reverser sleeves *H*, through the effect of a spring *J*, are taken into an intermediate position and the power flow to the axles of the vehicle is interrupted.

International Conference on Safety in Mines

OVER eighty delegates, representing fourteen countries, are attending the seventh international conference of directors of safety in mines research, which is being held this week at Buxton. The conference opened last Monday and will end to-morrow, Saturday, the meetings taking place at the Safety in Mines Research Establishment Field Station at Harpur Hill. The discussions at the conference cover many subjects, chief among them being firedamp explosions, the safety of electrical apparatus, coal dust explosions, mining explosives, mine supports, fire hazards, ventilation, methanometry and methane drainage. International co-operation in the study of safety in mines has now been in progress for many years, formal co-operation between the Safety in Mines Research Board of Great Britain and the United States Bureau of Mines having been established in 1924. The first international conference of officers in charge of research stations dealing with safety in coal mines was convened in July, 1931, and was attended by representatives of the United Kingdom, Belgium, France, Germany and the U.S.A. Three similar conferences were held prior to the war and two have taken place since. The British delegates at this week's conference include representatives of the National Coal Board and the Ministry of Fuel and Power.

Technical Reports

The All-Basic Open-Hearth Furnace: Special Report No. 46. London: The Iron and Steel Institute, 4, Grosvenor Gardens, S.W.1.—This report, which has been prepared by the British Ceramic Research Association and the British Iron and Steel Research Association, records the proceedings at the thirty-sixth steelmaking conference which was held in May, 1951, at Ashorne Hill, Leamington Spa. It includes seven papers dealing with various aspects of the performance of an experience with all-basic open-hearth furnaces, and also a report of the discussion on those papers. The papers constitute the second report of the All-Basic Open-Hearth Furnace Sub-Committee, which was formed just after the war by the two Associations convening the conference, to promote research on and the development of the all-basic furnace. The report shows that the economics of the all-basic furnace are still very much in the balance and that a great deal of development must occur before such furnaces find a general application.

MEDIUM POWER TESTS AT WENVOE TELEVISION STATION.—The B.B.C. hopes to start daily test transmissions on medium power from the new television station at Wenvoe on July 15, 1952, in readiness for the opening of the station on August 15th. The tests will normally take place each week-day, apart from the Bank Holiday week-end, between 11 a.m. and 12 noon and between 3 p.m. and 4 p.m.

The St. Lawrence Seaway Project

The St. Lawrence seaway project has been referred to in this journal at various times, but a fuller account of these important proposals is given below. The article is abstracted from a description appearing in this week's Board of Trade Journal.

WHILE the construction of the St. Lawrence Seaway still lies in the future, though perhaps the immediate future, much work towards it has already been done by both Canada and the United States, acting independently. For example, to overcome the great difference between the levels of Lake Ontario and Lake Erie, Canada has already constructed the Welland Ship Canal, by-passing the Niagara Falls. The United States, for her part, has already constructed the McArthur lock between Lakes Superior and Huron, and deepened the channels between Lakes Superior and Erie, though not to a depth of 27ft, which is envisaged for the project as a whole. The project now involves the construction of locks and canals to by-pass the rapids in the St. Lawrence River, and the deepening of parts of the rivers between the Great Lakes, to provide a channel at least 27ft in depth, navigable throughout for ocean-going ships from Belle Island on the Atlantic Coast, to Duluth at the western end of the Lakes, some 2600 miles into the heart of the North American Continent. At the same time, the hydro-electric power available from the steady flow of the St. Lawrence River would be developed by the construction of dams and power-houses giving 1,200,000 h.p. in the Lachine section at Montreal; 2,000,000 h.p. at Beauharnois, some 20 miles upstream (more than 50 per cent of this power has already been developed), and 2,200,000 h.p. in the International Rapids section between Ontario and New York State.

Following an investigation in the spring of 1951 by the Public Works Committee of the U.S. House of Representatives, the project, although not actually rejected, was shelved. This gave rise to considerable restiveness in Canada and, after a visit to Washington by Mr. St. Laurent, Canadian Prime Minister, in September, 1951, Mr. Truman, as President of the United States, declared that he would support an all-Canadian combined seaway and international power development scheme if it did not prove possible to obtain ratification of the 1941 agreement for joint international participation in both. Accordingly, a statute was enacted by the Canadian Parliament in December, 1951, providing for the setting up of a Federal agency to carry out the navigation works forming part of the joint power and navigation project. Another statute has also been enacted providing for the construction by the province of Ontario, in co-operation with the appropriate body in the United States (probably the Power Authority of the State of New York) of the power development in the International Rapids Section of the St. Lawrence River. Meanwhile, the United States Senate has voted in favour of the return of the Seaway Bill to Committee, which is tantamount to postponing the issue until the next session of Congress. It now seems likely, therefore, that Canada will construct the seaway alone, if agreement can be reached for international co-operation on the power project.

It has always been recognised by the various boards of engineers appointed to examine the project that the interests of navigation on the St. Lawrence are paramount. Various plans have been recommended from time to time, but this principle has always been upheld and the standards recommended for the proposed navigational improvements conform with those of the existing Welland ship canal and lock system. Channels will have a minimum depth of 27ft, and will not be less than 200ft wide on the bottom when flanked by embankments on both sides; greater widths will be provided when flanked on one side only or when both sides of the channel are submerged. On bends, the minimum radius of curvature of the channels will be 5000ft. All locks will have a minimum width of 80ft and length of 859ft, with 30ft depth on the sills. All bridges will provide a minimum vertical clearance of 120ft. The main items associated with the building of the complete combined project are given below.

Lachine Section.—The total drop from the average water level of Lake St. Louis down to the level at Montreal Harbour is 49ft over some 24 miles. At present, the rapids in the river are by-passed by the 8¾ miles long Lachine Canal which has a maximum depth of only 14ft. One of the most likely combined navigation and power schemes for the improvement of this section, which was selected by the 1947 board of engineers, is based on the assumption that the railway now using Victoria Bridge will be diverted through a tunnel to be constructed under the St. Lawrence River at Montreal, so releasing the Victoria Bridge for vehicular traffic only. With the railroad so removed, it will be possible to raise the levels of the bridge approaches to permit the main dam and power-house to be sited below the bridge. With this done, only one lock and a guard gate will be required to pass ships from Montreal Harbour to Laprairie Basin above the dam.

Dykes will be constructed on each side of Laprairie Basin to contain the headwaters and will extend some 9 miles upstream to just above the Lachine Rapids. Some considerable excavation and dredging will be required to provide a clear 27ft deep navigable channel on the south side of the river from the rapids at the head of Laprairie Basin to the entrance of Lake St. Louis. The channel through the rapids will have to be enlarged to ensure the formation of a winter ice cover throughout this section, and a guard lock will also be required at Caughnowaga. Movable spans will be required in the Canadian Pacific Railway bridge and the Honore Ste. Mercier road bridge over the river at Caughnowaga. Compensating and control works will also be constructed to permit partial control of the outflow and levels of Lake St. Louis.

As Montreal does not yet need the extra hydro-electric power available in this section, it is to be expected that the complete power-house will not be built and equipped until some time after the navigation improvements have been carried out. Initially, therefore, only a temporary dam, costing about 3 million dollars, will be required to close the actual power-house section of the dam. Construction later of the full power-house and tail-race, and the provision of machinery and equipment for 1,200,000 h.p. installed generator capacity, would cost about another 90 million dollars.

Soulanges and Lake St. Francis Sections.—Provision of 27ft navigation facilities through these sections is already well advanced by virtue of the new Beauharnois power development, carried out by the Quebec Hydro-Electric Commission on the south shore of Lake St. Louis, to which water is brought by a power canal from Lake St. Francis. This power canal has a 27ft deep navigational channel throughout, and has been designed to provide for future navigation; it will become available for this purpose when a guard gate and two twin locks in flight have been constructed in order to allow ships to pass from the canal to Lake St. Francis.

Replacement of certain fixed spans in two bridges over the canal by vertical lift bridges, and a railway and a road bridge over the lower entrance to the flight locks will also be required. Some additional dredging and excavation will be required to provide a clear 27ft channel through Lake St. Francis to the entrance of the power canal. All the above works are estimated to cost about 34 million dollars.

International Rapids Sections.—The best plan for the improvement of this section is called the "controlled single-stage project," as recommended for joint construction by the American and Canadian Committees in their 1941 report. It involves the construction of a main lower dam at Long Sault, and a dam and power-house at Barnhart Island of total installed capacity of 2,200,000 h.p. Also an upper dam would be constructed at Iroquois Point. The power generated would be shared equally between Canada and the United States.

The 1941 agreement made provision for the navigation canal to be situated on the American side, and to have two locks at Grass River and Robinson Bay to overcome the 85ft difference in water levels caused by the construction of the above-mentioned dams. However, if, as now appears likely, Canada carries out this project on her own, the canal and locks will be on the Canadian side of the river.

The dam at Iroquois Point will be a buttressed, concrete gravity structure, having a maximum height of 118ft above foundation, and will have a spillway flanked by concrete gravity sections and earth wing dams. The dam itself will consist of forty-one gate openings, 50ft wide, extending down to a continuous concrete sill.

The main lower dam, to be called the Long Sault dam, will extend from the United States mainland to the head of Barnhart Island and, together with the Barnhart Island power-house and flanking dykes, will complete the closure at this point. The dam will be a concrete gravity structure having a maximum height of 145ft above foundation. It will have forty spillway openings flanked by concrete gravity bulkhead sections, earth wing dams and dykes.

The Barnhart Island power-house substructure will be 3500ft long and 183ft wide. It will be divided at the centre by the international boundary, and each half of the power-house will contain one house unit and eighteen main generating units. The turbine installation now proposed will thus consist of thirty-six Francis generator units, rated at 61,100 h.p., each at best gate opening at 81ft head of water, providing an installed capacity of 2,200,000 h.p.

The flow at this point is 242,000 cusecs with maximum variations from 180,000 to 310,000 cusecs. The average head of water available will ultimately be 84ft, with maximum variations from 75·5ft to 87·8ft. Based on the flows and heads of water quoted above, the amount of power available, at 88 per cent overall efficiency, will be 2 million h.p. at 50 per cent load factor, and about 1¾ million h.p. at 75 per cent load factor.

The change in the water level which will be caused by the building of these two dams will flood about 10,000 acres of land on the Canadian side alone of the existing river. About one-third of the town of Morrisburg, and the whole of eight Canadian villages will be flooded and will have to be relocated. Twenty churches, fifteen cemeteries, 36 miles of existing double-track railway, and some 26 miles of main roadway, all at present situated below the new water level, will have to be relocated. The total cost of the works in this section has been estimated at 421 million dollars.

Welland Ship Canal.—The work begun in 1913 on the Welland ship canal was not completed until 1932, and some 132 million dollars have already been spent by Canada in this section. The 327ft lift from Lake Ontario to Lake Erie is now accomplished by eight locks, 859ft long, 80ft wide, and 30ft deep on the lock sills. All that remains to be done in this section is a little further dredging in order to deepen certain parts of the canal to a minimum of 27ft. It has been estimated that this will cost about 1½ million dollars.

Connecting Channels Between Great Lakes.—The natural outlet of Lakes Michigan and Huron is through the St. Clair River and the Detroit River into Lake Erie. The total fall averages 8ft, and the navigation channels have been progressively deepened by the United States until all that now remains to be done consists of some dredging necessary to provide a clear 27ft depth throughout and the construction of some submerged sills in the St. Clair River in order to raise slightly the average levels of Lake Huron and of the St. Mary's River below Sault Ste. Marie.

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APPLYING LOCOMOTIVE TEST RESULTS

THE decision of the Railway Executive to publish, in full and frank detail, reports of locomotive tests carried out on the Rugby and Swindon stationary plants, and their related road tests with dynamometer cars, is assured of a welcome from a wide circle of engineers and locomotive enthusiasts. In this, and preceding, issues of THE ENGINEER we have published a commentary on the first three bulletins issued, dealing with a Western Region "Hall" class 4–6–0, an Eastern and North Eastern "B1" 4–6–0, and a London Midland Class "4" 2–6–0. Other bulletins are promised, dealing, not only with steam, but with electric, diesel-electric, and gas turbine locomotives, while the knowledge that so interesting and controversial an engine as a Bulleid "Pacific" of the "Merchant Navy" class has been on trial at Rugby merely whets the appetite for more bulletins. But apart from the natural interest taken in the full thermodynamic performance of individual locomotives, such as those covered in the bulletins already issued, the ways in which such comprehensive tests may be put to practical use are almost unlimited. The comments contained in the bulletins themselves are written with the particular object of assisting the operating departments in so fixing train loads and time schedules as to run locomotives at their most economical rates of steaming. Suggestions are also made as to means of introducing accelerated timings with the minimum increase in coal consumption. Purely on the subject of engine performance some of the most revealing figures are those relating to the varying results obtained with different kinds of coal. The "Hall" class engine, in particular, of characteristic Great Western design, was definitely handicapped in the higher ranges of speed when burning a grade 2 hard coal, and this result makes one naturally curious to know how a "B1" 4–6–0 would have fared if fired with a soft Welsh coal instead of the "hards" on which she did so well.

The whole policy of subjecting important locomotive classes to scrutiny on one or other of the stationary test plants is likely to prove of immense value to the motive power stud of the country. One item alone from these bulletins is arresting in itself. The London Midland Class "4" 2–6–0 as received at Swindon was notably deficient in steaming capacity. The engine was not tested as such, but was first analysed and some simple alterations were made to the draught arrangements, with the result that the maximum steaming capacity was increased by 89 per cent. On reading such an item as this one cannot help wondering how many locomotives of indifferent reputation in former days were needing nothing more than some such simple modification to revolutionise their performance. It is good to know that the equipment and the technique exists for speedily laying bare the shortcomings of any present-day "black sheep." In general, the standard of performance revealed in these three bulletins is, in our view, very good. Many other classes of locomotives running to-day will, in due course, show very similar results so far as overall efficiency is concerned; but there is a vast disparity between the figures of coal consumption recorded in the controlled conditions of the tests, and the overall result in handling traffic, as represented by the actual coal used in the various regions. Published figures for the year 1950 showed average coal consumptions per engine mile ranging from 52 lb in the Western Region to 71 lb in the Scottish, whereas even at a really high rate of steaming the "B1" engine in express passenger service was not using more than 2537 lb of coal per hour, or 36·2 lb per mile.

The disparity between controlled test and actual coal consumption gives rise to several trains of thought. Referring back to the interchange trials of 1948, which were conducted in ordinary service conditions, some very significant results are to be found among the freight train trials. The "O1" 2–8–0 of the Eastern Region, a locomotive similar in basic design to the "B1" 4–6–0, made certain runs over the Midland line from Toton to Cricklewood with 1000-ton loads, and showed a very fair average coal consumption of 3·3 lb per drawbar horsepower hour. But whereas from the "B1" test bulletin just issued one might expect one of these mixed traffic 4–6–0s to haul 1000 tons at a steady 20 m.p.h. on some 40 lb of coal per mile, the actual runs of the coal trains in the 1948 road tests became so protracted that on one occasion the coal consumption was no less than 84 lb per mile. On this trip the train took 624 minutes to cover the distance of 128 miles and used 1430 lb more coal than on a previous occasion, when the same journey time was two hours less. Delays on the road were thus responsible for the use of an additional two-thirds of a ton of coal—on one journey. If it had been possible to work the train through at a steady speed, with no stops, the coal consumption might have been nearly halved, and halving in this case meant a saving of at least 2 tons. Such figures point to the need for planning all train schedules with the utmost care to avoid sources of delay. While delays of ten or fifteen minutes to an express passenger train can be infuriating to those on board, the side-tracking of a heavy freight for half an hour or more can involve a serious waste of coal. The removal of "bottleneck" sections, and points of congestion where freight trains and their engines are kept for long periods waiting "line clear," is an urgent necessity for the one purpose of saving coal, and we are glad to see that at last one of the most notorious of them all, at Potters Bar, on the East Coast main line, is about to be tackled. Since the war a great deal has been done, notably in Scotland, to improve the running of freight trains, and now the test bulletins published by the Railway Executive have shown clearly what savings are to be realised if modern locomotives are given a clear run with their loads. Mr. Riddles and the Locomotive Testing Committee of the Railway Executive are to be warmly congratulated on the skill with which they have presented the test results, while for our own part we look forward to the time when it will be considered just as serious an operating blunder to stop a coal train for five minutes as it is to-day to hold up the "Flying Scotsman" or the "Cornish Riviera."

TECHNICAL TRAINING OF ARMY OFFICERS

THE increasing complexity of fighting equipment as the result of the development of atomic energy, electronics, automatic computation, jet propulsion, antibiotics, and many other new systems and devices requires more and more officers in the Fighting Services who have a sufficiently advanced scientific education to enable them to interpret the needs of their Service to the scientist. The majority of Army officers now come from the public schools, particularly from schools in the South of England, and have been educated on an academic rather than on a scientific and technical basis. Very few lads join the Army from grammar and secondary schools, and though the Royal Navy is more fortunate in this respect, not enough boys of above the average standard take the examination for the Royal Naval College, Dartmouth, to complete the 50 per cent quota of naval cadetships allotted to State-aided schools. A boy has either to leave school at the age of sixteen because his parents need the money he will earn in industry or, if he is of a specially high standard and, incidentally, eminently suitable for the Fighting Services, his head-

master earmarks him to go on to a university.

Apart from an annual intake into the Army of some 120 officers from National Service men—who are selected from volunteers after a minimum of six months' service—regular officers start their officer training at the Royal Military Academy, Sandhurst, between the ages of eighteen and nineteen. Here about half their working time is spent on academic subjects and the more scientifically inclined are prepared for the university qualifying examination of Cambridge or London University. Some twenty of these go to Cambridge each year, where they do a two-year course, and are expected to pass the B.A. degree in mechanical sciences with honours. The remainder go to the Military College of Science at Shrivenham, where they are given a two- or three-year course leading to external London B.Sc. degrees in general science or engineering respectively. It must be emphasised that there are many opportunities for post-graduate work in the Army. Research work is carried out at the Military College, Shrivenham, and there are a variety of long courses which are designed to train specialists for the technical branches. At these courses officers work partly at military schools and partly on attachments to civilian firms. Courses are held in civil, electrical and mechanical engineering, railways, shipping, survey, wireless, radar and petroleum engineering—to name only a few subjects. Moreover, many of these courses enable an officer to qualify for associate member status of the appropriate professional institution, a qualification which may well be of great value to him when he is being considered for one of the higher technical appointments. But, in spite of all the facilities offered for technical education and advancement, the Army still needs many more technical officers. In an endeavour to overcome the shortage two new schemes are under development. The first, announced recently by the Secretary of State for War, is the opening next year of a college at Welbeck Abbey, Nottinghamshire, to take boys at the age of sixteen and prepare them for the more scientific courses at Sandhurst, with a view to their being given regular commissions, normally in the technical branches. The College will provide free education, on the lines of a British public school, for boys of sixteen to eighteen years of age, who would otherwise be unable to consider the possibility of becoming an officer in the Army. Within the next two years it is hoped to accommodate 150 boys, all boarders, and the school will be run on entirely civilian lines, with the civilian headmaster in complete charge of education and discipline. Normal cadet corps activity will be the only military training included in the curriculum. The other new scheme which the Army Council is hoping to introduce in the near future is a direct method of obtaining regular commissions, open to schoolboys, National Service officers and men, through the ordinary National Service officer training, followed by a degree course at the Military College of Science at Shrivenham. This would offer the certainty of a degree education combined with an early commission, but this new venture is still at the paper stage pending consideration of the financial and other aspects.

Of no less importance is the military training of the future technical officer. This he does first at Sandhurst—or during his National Service time in the case of the proposed direct entrant for the Military College of Science—and subsequently, either before or after his university education, he does the normal training peculiar to his branch of the Service at, for example, the School of Military Engineering or the School of Signals. Thereafter he begins his service as a trained officer, doing regimental duty with a unit of his corps, and returning to regimental duty at intervals throughout his career. It must be emphasised that he is not restricted in later life to technical or scientific employment. On the contrary, the highest ranks are open to him as a commander or staff officer. He is, of course, eligible for the entrance examination for the Camberley staff course and for the technical staff course, which is run at the Military College of Science. There can, indeed, be no better career for promising lads from secondary or grammar schools than to become an officer in one of the technical branches of the Army. Starting at Welbeck Abbey at the age of sixteen, a lad goes on to Sandhurst at the age of eighteen, or, if he prefers it, he may wait for his National Service and take his chance for selection for a commission to Sandhurst. Furthermore, if the new scheme is introduced, he will be able to get a regular commission after National Service officer training and a degree course at Shrivenham. In every case he does the training peculiar to his branch of the Service at its own school and completes his academic training by taking a Cambridge or London University degree. Later he specialises in any one of the various long courses leading in many cases to membership of the appropriate professional institution. And whatever branch he chooses, his future military career is in no way jeopardised by becoming a specialist. No matter what branch he is in, the higher ranks are open to him just as they are to any other officer.

Literature

The Welding of Non-Ferrous Metals. By E. G. WEST, Ph.D., F.I.M. London: Chapman and Hall, 37, Essex Street, W.C.2. Price 55s.

THE rapid growth in the application of welding to non-ferrous metals has, in the last few years, outstripped the authoritative documentation of this subject, but the author has largely put this matter to rights in his present publication. It is a book of some 500 pages, which deals with the welding of almost every conceivable non-ferrous metal and alloy, each receiving treatment approximately in proportion to the extent to which it is welded in practice. The author, who is technical director of the Aluminium Development Association, published much of the subject matter of this book some few years ago in serial form in the journal *Sheet Metal Industries*, as a result of a vast amount of study of existing literature and current practice.

The text is based upon sound fundamental metallurgical considerations, and this gives a good foundation to the more practical aspects which are considered in sufficient detail to enable those about to start or already engaged in welding non-ferrous metals to choose and apply the most appropriate welding process. It is divided into fifteen chapters, the first five of which deal generally with weldability, properties important in welding, and the three main processes, viz., fusion welding, resistance welding and pressure welding. The next six chapters specifically cover the welding of various non-ferrous metals and alloys, and in particular alloys of aluminium, magnesium, copper, nickel, lead and zinc. The three concluding chapters deal briefly with welding of other metals of less industrial interest, such as tin, bismuth, tungsten, molybdenum, tantalum, chromium, and the precious metals.

Early in the book a comprehensive table is presented, the object of which is to give at a glance the applicability of all the major welding processes to each of the non-ferrous metals and alloys. The value of such a table is obvious, and its preparation must have presented a formidable task. Inevitably, such a table which classifies each process into one of three degrees of suitability must contain debatable borderline cases. For instance, the butt and flash welding of copper is not considered to be a recommended method for this material, but only a possible method of limited use. It is, however, a fact that butt and flash welding of copper is extensively practised in the wire-drawing and electrical industries at present, and the quality of the joints obtained is particularly high, as is evidenced by the fact that such joints can withstand the high stresses imposed in wire-drawing. Again, butt welding is rapidly replacing soldering and brazing for joining electrical windings in motor stators, and in this important field of application butt welding is advantageous in that it produces a joint in which the electrical properties of the windings are not appreciably impaired at the joint, as can be the case with soldering or brazing.

Popular phrases, which are in deplorably wide use in arc welding in its various forms, are "straight" and "reverse" polarity, as applied to the way in which the electrode and work are connected to the output of a d.c. welding machine. The American conception of straight polarity is the opposite of that generally accepted in this country. The author has, however, chosen the American method, and many users of arc welding may be misled by this. It is to be hoped that more use will be made in future of clearer and more objective terms, such as "electrode negative" or "electrode positive," terms which cannot in fact be misinterpreted.

An interesting but all too brief section on argon-arc welding contains reference to costs as compared with oxy-gas and metallic arc welding. In this, the author has omitted to take the opportunity to emphasise the greatly reduced finishing costs involved in grinding and dressing down the weld after argonarc welding. In many instances it has been shown that the reduced finishing costs greatly outweigh the higher costs of operation of the process as regards consumable materials, notably argon gas. The "Aircomatic" or self-adjusting arc process is disposed of in a matter of less than one page, which is perhaps inadequate for a process which is now making possible rapid and high-quality welding of heavy sections in situ in aluminium alloys.

Other minor criticisms might be made of such things as the apparent lack of soundness of the treatment of electrical and general engineering matters, but unduly to emphasise such shortcomings would not be conducive to viewing these defects in their correct perspective, bearing in mind the generally high standard which the book reaches. As a reference book it will be found invaluable to all those connected directly with welding, and also the designer, works

engineer and metallurgist. It is profusely and accurately illustrated, and for those who wish to examine more closely some of the facets of the subject of which space has not permitted a fuller treatment, 353 subject references to original papers have been included.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE FUTURE DEMAND FOR COAL

SIR,—I refer to Mr. Gamlen's letter, which was published on June 27th, and a number of criticisms are necessary. It seems a pity that, before writing the letter, he did not pay sufficient attention to the evidence published by the Federation of British Industries in *A National Fuel Policy* (February, 1952). This publication does, in fact, give the answers to a number of the points which he raises.

It is by no means clear what effect the present trade recession is likely to produce, but if recent trends continue there is every reason to suppose that national coal consumption will exceed national production by some 50 million tons in another ten years' time, and, of this increase, 27½ million tons will be required by the B.E.A. to meet the increased demands necessitated by its programme for power station construction. It is this fact which is worrying fuel technologists. The report of the Ridley Committee is due for publication in a matter of months, and it would seem prudent to wait for this publication before becoming dogmatic on the subject.

Each one of us would like an unrestricted supply of electricity both in homes and in factories. Not only is it convenient, but, because it is clean, can contribute materially to the reduction of atmospheric pollution. Electricity, gas and solid fuels each have their uses, and a national fuel policy must embrace the three nationalised industries, so that each is used in the field where it is most efficient from the point of view of coal utilisation. In a recent letter to *The Times*, Mr. F. G. Brewer, Secretary, the Gas Council, stated that to provide the equivalent of 75 therms of gas, which requires 9 cwt of coal, 1500 units of electricity have to be generated, and to produce 1500 units of electricity 15 cwt of coal would be required. I refrain from mentioning such important by-products as coke and tar. These figures more than confirm the Simon Report, which gives the "coal economy efficiency" of gas as about 30 per cent and electricity as 18 per cent, measured at the point of continuous use. Accepting the standard set by Egerton, an average council house, without electric cooking would require 10,000kWh for space heating, representing a consumption of about 7½ tons of coal per annum at the power station. Lant and Weston (*Journal Institute of Fuel*, May, 1952) show that modern solid fuel heating systems can show efficiencies of well over 50 per cent. A few months ago, Sir John Hacking, referring to space heating, advocated solid fuel for constant use, with electricity or gas for intermittent use only. Because of restraints which involve discomfort, if not hardship, domestic coal consumption has fallen from 45·8 million tons before the war to 32·4 million tons in 1951, and this is the main reason for the rapid increase in the domestic use of both electricity and gas, a factor not without its influence on the incidence of power cuts.

According to the latest published report, the average thermal efficiency of B.E.A. generating stations is only 21·79 per cent, although it is expected that this value will reach 26 per cent by 1960. Each new station should have an economic life of thirty years, and, according to Dr. Roxbee Cox, steam turbines, whilst capable of further improvement, have reached a stage of development where major advances in overall economy are no longer probable. It follows that there is a very strong case for examining the possibility of installing back-pressure generating plant, not only for factories' use, but also very often in connection with district heating schemes. With back-pressure installations the thermal efficiency of the prime mover itself does not matter, provided that good use can be made of the latent heat in the steam which passes through it. In ideal circumstances, with a perfect balance between heat and power requirements, a coal utilisation efficiency approaching 80 per cent can be reached. The Minister of Fuel and Power is reported in *Hansard* for March 7th as stating that both the Government and the B.E.A. wish to encourage the installation of back-pressure turbines in suitable factories.

It is important to note that it is not only in B.E.A. power stations that inferior coals can be burned. Many large factories have similar water-tube boilers, while, owing to the rapid development of small mechanical stokers in recent years, such fuels as pit-mound slack, coke breeze, slurry and peat can now be consumed satisfactorily in shell-type boilers, without smoke emission. By burning inferior fuels in industrial power stations, both large and small, more good coal can be made available for export. It is only by making the very best use of our coal resources that the coal export trade can be restored to its healthy pre-war condition, and this is a matter of the highest economic importance.

JOHN FOX,
M.I.Mech.E., Associate I.E.E., F.Inst.F.

Hove, July 2nd.

PRESENT-DAY LOCOMOTIVE WORKING IN GREAT BRITAIN

SIR,—I have read Mr. Robson's letter in your issue of June 20th which draws attention to locomotive cylinder performance, being a point to which Mr. Robson has referred on other occasions. It is quite true that, from the point of view of power output, locomotive cylinders fall far short of what can be, and is, attained with other forms of engines.

This is due, as Mr. Robson says, to the valves and valve gears commonly employed, which very definitely restrict power output. It is quite extraordinary when one comes to think of it, and not many do, that reliance is placed on a valve gear which actually mechanically restricts admission port openings when the gear is set for high-speed running and when, under any conditions of admission rates and port openings, throttling alone will and, in fact, is bound to, affect adversely cylinder steam pressures. The truth is that, in general, no progress has been made in the steam distribution in locomotive cylinders since 1899, when Alex. Vogt designed a high-speed "Atlantic" for the Pennsylvania, and provided semi-balanced valves with a steam lap of 1¼in and a maximum travel of 7in, featuring also a negative lead in full gear. Cylinder ports have been improved, but they are no better than the design used by Drummond on the Caledonian in 1889. Definitely to what extent it is possible to improve cylinder powers at high speeds and at economical admission rates has not been clearly established in this country.

In America, however, it would seem that at maximum speeds under maximum power conditions, a poppet valve gear has shown an improvement of close to 40 per cent. In view of the fact that passenger engines, and one may say perhaps others in service at the higher ranges of speed, do all their work on the drooping portion of the drawbar horsepower curve, it is clearly important to improve cylinder performance by designing a valve gear that will provide maximum port openings to admission at running cut-offs and not minimum openings, as at present. It is an open secret that the Railway Executive is interested in this phase of locomotive designing and has a locomotive in regular service fitted with a new rotating cam-operated poppet valve gear, which indicates definite improvement in cylinder power output, probably, as the writer stated recently at a combined meeting of the Institute of Fuel and the Institution of Locomotive Engineers, of at least 20 per cent at medium express speeds. It will therefore be appreciated that, along with the further development of the two-cylinder locomotive, the Executive is also fully alive to the desirability of attempting improvements in performance. It is both fair and proper that this should be recorded.

E. C. POULTNEY

London,
June 30th.

BRITISH LOCOMOTIVE PERFORMANCE AND EFFICIENCY TESTS

SIR,—On page 30 is a statement (it is not clear whether it originated with the Railway Executive or with Mr. Nock) that "the cut-offs necessary to produce the power were considerably less on the 'Hall' than on the 'B1,' thus indicating the difficulty of attempting to assess the relative merits of work by dissimilar engines without reference to all the measured data."

The relative merits established by the tests concerned are those of power output and overall efficiency in a variety of conditions of load and speed. A cut-off figure is not a relative merit, and no useful purpose is served by considering it when examining the figures presented for power and efficiency. The cut-off figures introduce difficulty only to those who do not realise their irrelevance.

If, as a point of somewhat academic interest, it is desired to know how different cut-offs in different engines can lead to a common power output, it is then necessary to consider additional factors such as speed, cylinder volume, clearance volume, mean area of port opening, and crank angle at admission.

In assessing anything, it is necessary not only to examine all the relevant data, but also to disregard the irrelevant ones. Discrimination between relevant and irrelevant data demands clear understanding of basic essentials. In the absence of that understanding even such a simple machine as the steam locomotive may present all manner of mysticism.

W. A. TUPLIN, D.Sc., M.I.Mech.E.

Sheffield,
July 5th.

BOOKS RECEIVED

Steam Turbine Theory and Practice. By William J. Kearton. Sixth edition. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 35s.

Advances in Applied Mechanics. Vol. II. By Richard von Mises and Theodore von Karman. New York: Academic Press, Inc., Publishers, 125, East 23rd Street, New York, 10, N.Y. Price 6·50 dollars.

Electro-Plating, A Survey of Modern Practice. Sixth edition. By Samuel Field and A. Dudley Weill. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 20s.

Flow Measurement with Orifice Meters. By Reid F. Stearns, Russell R. Johnson, Robert M. Jackson and Charles A. Larson. London: Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 56s.

Redgrave's Factories, Truck and Shops Acts (Supplement to Seventeenth Edition). By John Thompson and Harold R. Rogers. London: Butterworth and Co. (Publishers), Ltd., Bell Yard, Temple Bar, W.C.2. Price 10s.

A Modified Farnboro Electric Indicator*

By W. J. R. ROACH, B.Sc., and J. G. G. HEMPSON, A.M.I.Mech.E.

No. II—*(Concluded from page 9, July 4th)*

The development of an apparatus and operating technique for determining the mechanical efficiency of large marine oil engines is described and the shortcomings of existing equipment for measuring indicated mean effective pressures are discussed. There is a description of a modified Farnboro indicator which makes use of the movement of a flexible diaphragm to initiate signals to an electronic relay, which causes time and pressure to be recorded. The torsional rigidity necessary in the indicator drive is noted and also the need for accuracy in marking dead centres.

The Pressure Balance Pick-up or "Diaphragm Unit"

A STUDY was made of the British, German, American and French published work on the subject of the signalling of pressure balance. This went back as far as 1878. The broad details of the unit and electronic relay designed as a result of this survey have remained relatively unchanged, development being almost entirely confined to materials, minor changes of construction, and the values and types of electrical components and their most effective physical arrangement.

The jumping disc valve, whose motion is detected by electromagnetic means or capacitance change, was ruled out. This unit has no positive seal between combustion gases and the applied pressure and cannot be operated continuously for long periods owing to oily

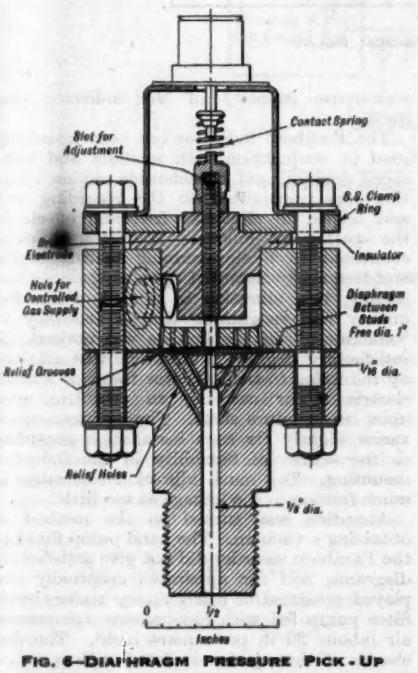


FIG. 6—DIAPHRAGM PRESSURE PICK-UP

and carbonaceous fouling, and at low rates of pressure change it is not effectively free from hysteresis, which can be increased to an unknown extent if oil is present. The method adopted was the use of an unstressed diaphragm of negligible stiffness moving between stop plates, this has proved satisfactory and a typical unit is shown in Fig. 6.

The unit, known as a diaphragm unit, will operate with a pressure differential of less than 0·05 lb per square inch at low pressures and low rates of pressure change and at the same time will withstand continuous operation for some hours under conditions imposing cyclic maximum pressures of 1300 lb per square inch in a high-speed compression-ignition engine.

The illustration shows that venting by grooves is provided in both stop plates to avoid pressure hysteresis. By making variations between no grooves and a large number it was found that above a certain number there was no further improvement.

The method of clamping the diaphragm has proved satisfactory, no gas leakage having been observed at the periphery when careful attention has been given to cleanliness during assembly. Prestressing of the diaphragm, and consequent inaccurate operation, has been avoided by this means and by the use of a low-modulus material carefully heat-treated. The body of the unit has been constructed from free-cutting stainless steel, and mild steel cadmium-plated has proved a satisfactory material for studs and set bolts.

Electromagnetic means or capacitance change to produce a signal from the movement of the diaphragm were rejected in favour of direct contact between the diaphragm and an insulated electrode. The indirect methods mentioned were discarded because they depend upon the velocity of movement of the diaphragm (or free disc) to generate a large enough signal to operate the electronic relay. There will be a limiting rate of change of pressure below which the apparatus will cease to operate. The waveform of the voltage produced by such devices changes with velocity and hence phase errors of the triggering point will occur unless considerable amplification and limiting are used. The use of large amplification entails increased liability to triggering by spurious signals and thus the specification as to insensitivity to cable conditions is violated. Capacitance-change methods of triggering the electronic relay, when used with simple circuits, involve high input impedances, the inability to use long high-capacitance cables, and the need to maintain very high standards of insulation. More elaborate circuits using frequency modulation involve a quite unacceptable degree of complication.

The contact method avoids these difficulties. The impedance is low, of the order of 10,000 ohms, and the signal produced is of the order of 10V. The appropriate circuit being relatively non-inductive, this voltage is not high enough to produce any arcing at the contacts. During development liberties have been taken with cables to demonstrate the insensibility of the equipment to interference. Up to 100 yards of single-core unscreened cable have been led through known sources of interference without noticeable effect. The resistive leakage has to be exceptionally large to have any effect, and little trouble due to the low voltage and current has been experienced with the contact surfaces. Cleaning is only infrequently required and may be carried out with commonly used materials, but future contact points and diaphragms will be plated with a corrosion-resisting metal to effect further improvement in this respect. The large signal produced renders unnecessary any great amplification in the relay unit.

Only one case of the failure of a normal diaphragm has been experienced and this was due to incorrect adjustment of the central electrode. Replacement or cleaning needs no special skill or readjustment. The use of flat or slightly dished surfaces and straight passages facilitates cleaning, although heavy fouling, even under the severe conditions of an engine burning heavy boiler oil, has never been experienced. This is due to the efficient sealing of the diaphragm, which prevents through flow of the combustion gases.

The Electronic Relay

This relay is of a simple nature, and is relatively insensitive to supply voltage and frequency fluctuations. Two types of unit have so far been constructed. Fig. 8 shows the circuit diagram and Fig. 7 a photograph of the first; it can function in three ways. The signal from either the dead centre or the diaphragm units provides either a pulse of sufficient magnitude to produce the required spark at the Farnboro recording drum or a continuous stream of sparks for marking calibration and atmospheric lines. Fig. 9 and Fig. 10 show the corresponding details for the second unit, to which the pre-amplifier and connection for dead-centre indication has not been fitted, the aim being to obtain the optimum performance from the pulse-generating portion of the circuit and to reduce the size of the equipment.

The design of both circuits is very similar. One double triode valve is used as amplifier and phase splitter and two thyratrons act as pulse generators. Gas-discharge regulators are included for voltage stabilisation in the first unit, but as will be seen in Fig. 9, one only has now proved necessary, this stabilising the thyratron bias and diaphragm-unit supply voltage. Metal rectifiers are used for reliability and the number of electrolytic condensers kept to the minimum. The transformers are of the standard tropical radio type. From Fig. 9 it should be noted that a paper dielectric condenser is fitted in the reservoir position of the power pack where it is subjected to ripple and separate secondary smoothing condensers of large rating margins

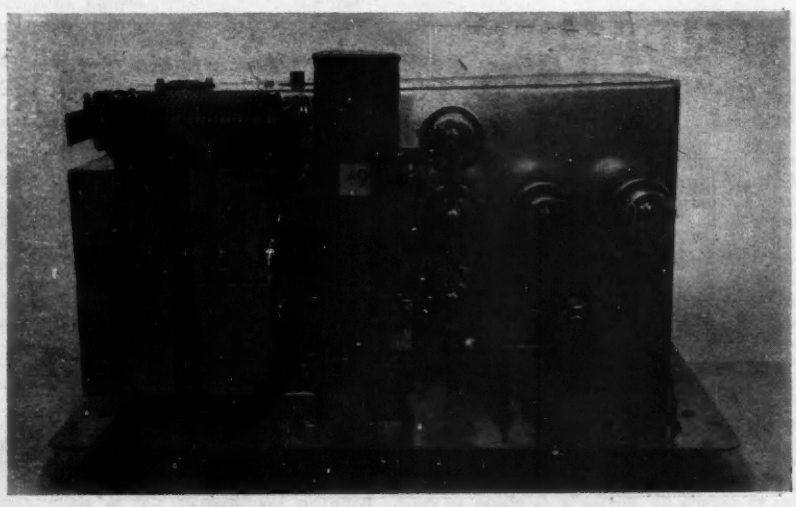
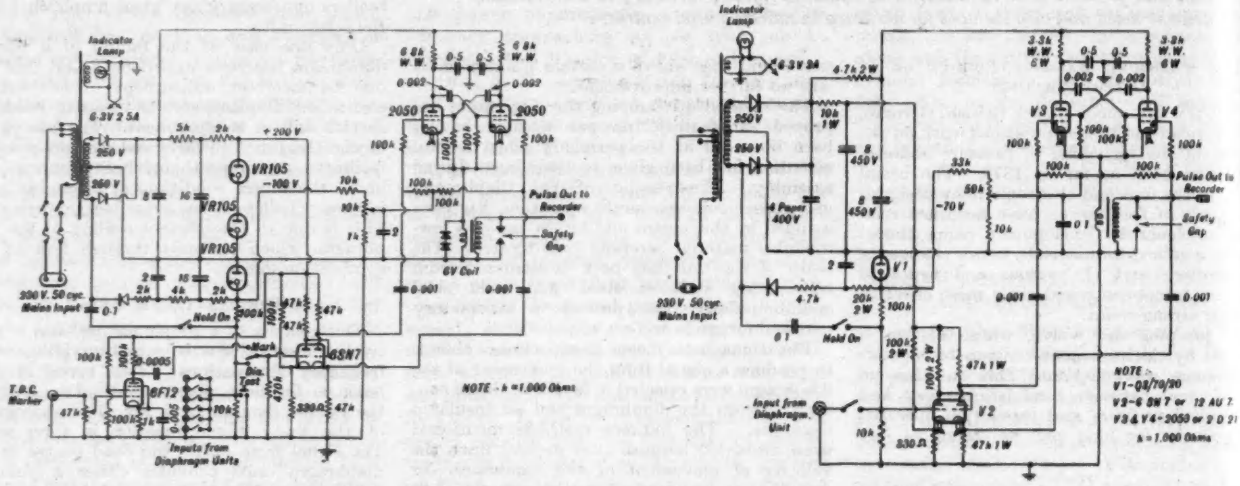


FIG. 7—FIRST FORM OF ELECTRONIC RELAY

* British Shipbuilding Research Association Report No. 93.

are used for the amplifier and thyratron sections to avoid interference from the large voltage swing produced by the latter. The negative bias supply is obtained from the same winding as the h.t. supply by means of a separate half-wave rectifier. This voltage is somewhat critical and stabilisation by the gas-discharge tube is necessary to allow operation without adjustment over a wide range of supply voltages. Resistive smoothing is satisfactory and saves the weight and bulk of a choke. Provision is made for feeding a.c. two condensers no loss occurs, the limitation being the time interval between successive peaks of a repetitive wave form. On the assumption that condenser recharge to 200V is sufficient for an effective pulse, the interval between peaks must be 1·5 milliseconds or more.

The coil transforms the current pulse produced by the condenser discharge into a voltage pulse of at least 6kV peak value. In the first unit a 6V car ignition coil was used, but has been discarded. The primary induc- was difficult to operate, since it was impossible to avoid jerking of the spark point when the valve was first opened. A satisfactory modification was the fitting of a separate high-pressure shut-off valve in the supply line. Thus the needle control valve need not be completely closed after taking a diagram, the shut-off valve being shut. On opening the shut-off valve the partially opened needle valve prevents a surge of pressure, thus ensuring smooth motion of the spark point. This surge is probably accentuated by the relatively large



FIGS 8 AND 9—CIRCUIT DIAGRAMS OF TWO FORMS OF ELECTRONIC RELAY

to the input to produce continuous sparking for calibration purposes. The double triode in both relays is an octal-based "6SN7," but could be replaced by the electrically identical miniature "12AU7". Tetrode thyratrons are fitted, type "2050" in the first unit and the miniature type "2D21" in the second. These thyratrons having a large control ratio can operate with a small triggering signal. In addition a signal is fed from the anode of one to the suppressor grid of the other to eliminate sympathetic triggering. These measures render the operation very stable and little affected by the only control, which is an adjustment for the hold-off bias of the thyratrons. This only requires adjustment when valves are replaced or when operating conditions are exceptional. Two discharge condensers are provided, allowing consecutive pulses to be produced at an interval governed by the characteristics of the spark coil. With a single discharge condenser there would be an appreciable time interval before a second pulse could be delivered, resulting in loss of continuity of line in steeply peaked wave forms. With tance was too high, limiting the spark repetition rate and under certain conditions giving double pulses unless a damping diode was connected across the primary. After experiment a coil of reduced inductance and simple construction was produced. This weighs only 3 oz to 4 oz and shows greatly improved characteristics besides a saving of weight and space.

Fig. 8 shows the additional pre-amplification stage fitted for use with the electromagnetic dead-centre pick-up units. This employs a "6F12" valve, and a potentiometer provides control over the magnitude of the output signal. It is desirable to limit the amplification to the minimum necessary for certain triggering in order to ensure the greatest accuracy.

Modifications to the Farnboro Recording Unit

During development several modifications to the standard arrangement of the recorder proved desirable, to obtain greater clarity and accuracy of diagram.

The standard needle control valve for admitting high-pressure gas to the indicator system volumetric capacity of the indicator pipe lines.

The Farnboro indicator has been invariably used in conjunction with medium and high-speed engines, and considerable engine vibration was transmitted to the recording unit and helped to eliminate frictional effects in the spark-point linkage. With the indicator connected to a slow-running marine engine and frequently mounted upon an independent seating, this vibration is of such a low frequency and magnitude that a tendency to "stickiness" in the linkage was noticed. A satisfactory degree of vibration was attained by the fixing to the indicator frame of a small electric motor carrying an eccentric mass upon its armature shaft. The optimum speed varies slightly for each installation according to the degree of flexibility in the indicator mounting. Too much vibration can cause as much friction in the linkage as too little.

Attention was turned to the method of obtaining a vacuum. The hand pump fitted to the Farnboro recorder did not give satisfactory diagrams, and the apparatus eventually employed consisted of a laboratory water-ejector filter pump fed with low-pressure compressed air (about 20 lb per square inch). The discharge of this ejector is fitted with a valve. Suppose the apparatus to be working and producing full vacuum, the outlet valve is slowly closed and the vacuum will then die away and a positive pressure will build up in the indicator line with no discontinuity at atmospheric pressure. This gives a smooth motion of the spark point throughout the "light-spring" diagram, and makes possible the accurate recording of phenomena occurring in the region of atmospheric pressure.

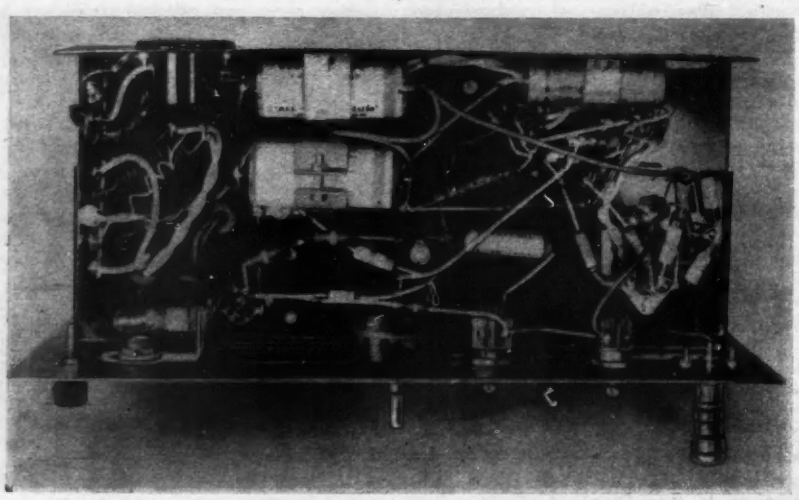


FIG. 10—SECOND FORM OF ELECTRONIC RELAY

High Pressure Gas System

Fig. 11 shows a simplified piping diagram. The gas cylinder contains commercial nitrogen at a nominal pressure of 1850 lb per square inch, and is connected by a length of annealed high-pressure copper tubing of ¼in outside diameter to the indicator shut-off valve. The use of nitrogen has been found beneficial in reducing deposits and corrosion in this system.

The controlled-pressure connection of the indicator is coupled to a distribution block mounted at a position midway along the engine at indicator cock level and individua

pipe-lines are run to each diaphragm unit mounted on the indicator cocks. A "T"-piece is included in the pipe-line from the indicator and is coupled to a standard reference gauge reading to 1000 lb per square inch maximum.

Electrical System

Although the electronic apparatus is relatively insensitive to variations in voltage and frequency it has been found convenient to employ a motor-alternator unit to supply 230V, 50 c/s to the set, as few ships and not all shipyards have this available at the engine to be tested. The B.S.R.A. testing gear can therefore be worked from supply mains having the following characteristics: 200V to 250V, or 100V to 140V d.c., and 200V to 250V a.c. at 40 to 60 c/s.

Operation could also be arranged from an accumulator and vibrator unit.

All power leads employed on test are constructed of double or triple-core stranded copper cable, 7×0·029in or 3×0·036in, insulated and sheathed with polyvinylchloride. For interchangeability the leads from the electronic unit to both the diaphragm units and dead-centre pick-ups are of screened coaxial construction, polythene insulated with p.v.c. sheathing, as this obviates any possibility of spurious sparking due to interference with the dead-centre marker circuit from existing ship's electric circuits although no screening is necessary for lines to the diaphragm units. A satisfactory alternative has been found to be twin-core screened microphone cable, p.v.c. sheathed.

Operational Procedure

The method of obtaining a diagram from the cylinder of a slow-running marine engine is as follows:—

(i) The special indicator paper is affixed to the recorder drum and all circuits are switched on and adjusted; (ii) the selector clutch is set so that the diagram obtained will lie in the centre of the paper and the Farnboro clutch is engaged, causing the drum to rotate; (iii) with the vent valve open to atmosphere and the gas shut-off valve closed the calibration switch on the electronic unit is pressed, the ensuing stream of sparks thus marking the atmospheric line; (iv) the appropriate indicator cock is opened to its diaphragm unit and the correct circuit switch closed; (v) the main control valve being "cracked" the shut-off valve is opened; the pressure in the system will then rise at a rate controlled by the needle valve, the diagram meanwhile being sparked on the paper. The optimum rate of pressure increase is about 1000 lb per square inch per minute, although a slower rate may be desirable at the commencement of the diagram and again when approaching the maximum engine cylinder pressure. This slower rate maintains the spacing of points on those portions of the diagram which have a low rate of change of pressure. Care must be taken that the application of pressure is sufficiently rapid and smooth to obviate jerking of the indicator piston; (vi) the moment the applied pressure exceeds the highest maximum pressure attained in the engine cylinder, all sparking will cease. The pressure is allowed to rise a further 50 lb per square inch and the changeover switch is moved from the "diagram" to the "marker" position. The dead-centre line or reference lines will then be available on the diagram, the full length being sparked by shutting off the pressure and "cracking" the vent. Meanwhile the diaphragm-unit circuit switch is moved to the off position. The marker circuit is again isolated by moving the changeover switch back to the diagram position, this being done a little before the spark point has moved right back to the atmospheric position, eliminating the possibility of confusion of spark holes; (vii) the indicator cock is shut; (viii) a pressure calibration can be effected by allowing the recording drum to rotate, closing the vent valve, and increasing the pressure at the rate employed during (v) above. The standard reference pressure gauge is watched and the calibration button on the electronic unit is pressed momentarily at suitable increments of pressure. This records on the diagram and the effective pressure scale can be measured. Care should be taken that the spark point does not halt or fall back due to faulty manipulation of the control valve during either diagram recording or calibration as this will vitiate the automatic elimination of frictional errors in the measurement of mean pressure.

Figs. 12 and 13 show typical diagrams obtained during normal testing.

An estimation of the absolute accuracy of mean-pressure figures obtained from the indicator diagrams cannot be arrived at directly, owing to the lack of an accurate basis for comparison. However, it may be of some use to note the order of accuracy of the individual units of the apparatus. The possible errors may be divided into three groups: mechanical, electrical and analytical.

Errors Having a Mechanical Origin

In spite of the precautions the presence in the recording unit of a piston and cylinder together with the associated linkage gives rise to mechanical friction, which will tend to cause the pressure recorded at any instant to be slightly lower than the actual applied pressure. By the addition of the vibrator unit and careful maintenance of pivots and piston it has been found possible to reduce this frictional effect to the order of 10 lb to 15 lb per square inch for power diagrams, and to much less than this when no external springs are fitted. This frictional effect is eliminated when a diagram is measured for mean pressure, since both compression and expansion sides of the diagram are recorded simultaneously and, in calculating mean pressure, the compression line is in effect subtracted from the expansion line. The frictional error remains if actual pressures are read off the diagram, being equivalent in a power diagram to a displacement of the atmospheric line. In order that this error may be determined all diagrams and calibrations are taken with applied pressure rising. If accurate pressure readings at particular points are desired the friction error can be found by sparking on pressure calibrations with rising and falling pressures and on the same diagram. The reference pressure gauge must also be checked on a dead-weight testing machine with both rising and falling pressures as the gauge errors may vary. After allowing for gauge errors the recorder frictional error at any desired pressure is then half the difference between the two calibration lines and it will be found to be nearly constant over the indicator spring range.

A further error in the recorded pressure may be caused by too high a rate of pressure rise, especially when a large engine is under test. The volumetric capacity of diaphragm units and pipe-lines is not negligible and a flow of gas in the main pipe-line is needed to raise the pressure on the units. If this flow is rapid, an appreciable pressure drop may be caused in the line and the recorded pressure may exceed the actual pressure on the diaphragm. The ultimate error is partially eliminated when measuring off mean pressures, but will affect spot measurements.

The diaphragm units may give rise to certain errors due to: diaphragm inertia (including entrained gas), passage lengths between diaphragm and engine cylinder, the differential pressure required to cause the diaphragm to break contact with a backing plate and commence moving.

The first and third sources cannot readily be separated and estimated with any useful accuracy, but recent experiments have shown that the time lag between a change of cylinder pressure occurring and the transmission of a signal from the pick-up unit is considerably less for the diaphragm unit than for some electromagnetic and condenser type commercial units. For low rates of pressure change the former shows a lead of several milliseconds. Experiments are in hand to obtain a reliable figure for this time lag under various conditions of pressure and rate of change of pressure. The small effect of differential pressure on the accuracy of indication is shown by the fact that a test engine motored under steady conditions showed no difference in apparent maximum compression pressure whether the applied pressure was rising or falling when passing through the pressure-balance point. Indications are that the combined effect of diaphragm and gas inertia and differential pressure will be to cause a time lag of not more than 1 millisecond at a low rate of pressure change, such as exists in a marine oil engine cylinder at the commencement of the compression

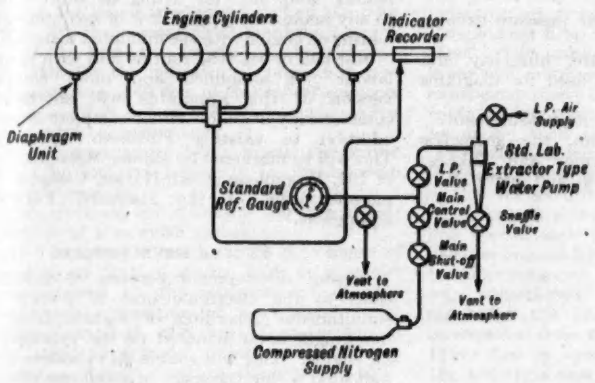
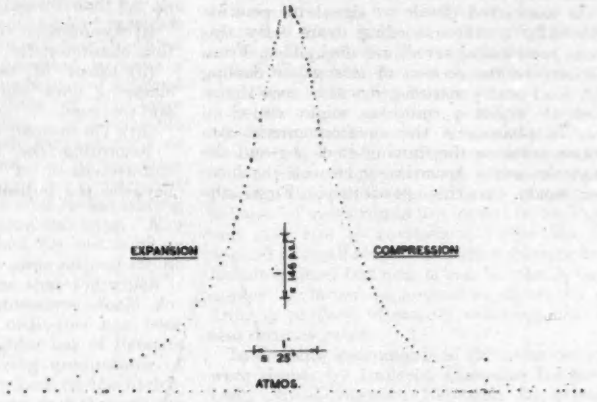


Fig. 11—Piping Diagram of Modified Indicator



4 s.c., C.I. Engine; 85mm bore, 800 r.p.m. Pool diesel fuel.

Fig. 12—Typical Indicator Diagram at 800 r.p.m.

stroke. The effect of indicator passage length is to add a further time lag because the speed of sound in a gas is finite. A change of pressure in the engine cylinder is communicated to the indicator by a pressure wave in the connecting passage and this pressure wave will move at a speed approaching the speed of sound in the gas. No troubles have been experienced due to vibratory effects in a long passage. On many engines the length of passage is a minimum, the ideal probably being a diaphragm unit at the centre of the actual piston, but on certain engines the passage length may be from 12in to 18in in length and the corresponding mean time lag of the order of ¼ millisecond.

A slight lag occurring in the marking of the top centre line will have the effect of reducing the total error, since such lag will have the same effect as a lead of the diagram relative to the true top centre.

Errors Having an Electrical Origin

Accurate phasing of the diagram in relation to the movement of the piston is of paramount importance for all work involving the measurement of mean pressure. The only way to obtain accuracy is to cause either the piston or its associated crank to signal its position electrically to the recording drum. By this means mechanical errors are negligible. From reference to the section of this paper dealing with dead-centre marking, it will be seen that a point at which a time lag might cause an error in phasing is the electromagnetic connection between the moving steel peg and the magnetic unit. Accordingly two checks have been made on this possibility. First, the signal from the magnetic unit was made to actuate a neon tube placed near the unit and peg in an experimental rig, the linear velocity of the peg past the unit being of the same order as that existing in actual engines tested. The effect of polarity and bias on the grid of the thyratron valves was then observed and it was found that, with the polarity correct, the bias control had a very small effect upon the time interval between coincidence of peg and magnetic unit and the "firing" of the thyratron. With polarity incorrect, operation of the bias control caused appreciable variation in time lag. When the magnetic unit was connected with correct polarity the linear lag observed was in no case greater than the thickness of the chisel point of the peg, i.e. 1mm. In a slow-speed marine engine of 1200mm stroke this would correspond approximately to 0·095 deg. of rotation, and in most cases the error would be less. In other words the maximum error in mean pressure due to this cause would be rather less than 0·5 per cent. A second test was made during a recent trial by recording, on the same diagram sheet, dead-centre reference lines for both ahead and astern running. In this case no measurable phase difference could be found. One-half deg. is equivalent to approximately ½mm on the diagram.

Turning now to the diaphragm-unit circuit the time lag associated with the electronic unit is the delay between the signal being received from the unit and the passage of the spark at the recording drum. This lag was estimated at a few microseconds and was investigated as follows: a tapping from the input to the electronic unit was taken to a cathode-ray oscilloscope together with a tapping from the high-voltage output from the spark coil and the operation of the electronic unit then compared on a time basis by means of an 8kc/s wave trace. No measurable lag could be observed and it was concluded that the error caused by delay in the electronic unit would be negligible on the time or degree scale of the indicator.

The diaphragm unit actuated by the engine cylinder pressure cannot introduce appreciable electrical time lags, the characteristics of the electronic unit being such that the current flowing through the contacts when closed is less than 1mA, and the make and break of this current is effectively instantaneous.

Errors Arising During the Measurement of Diagrams

Errors under this heading may be caused by:—

(i) Assumption of a linear pressure calibration characteristic.

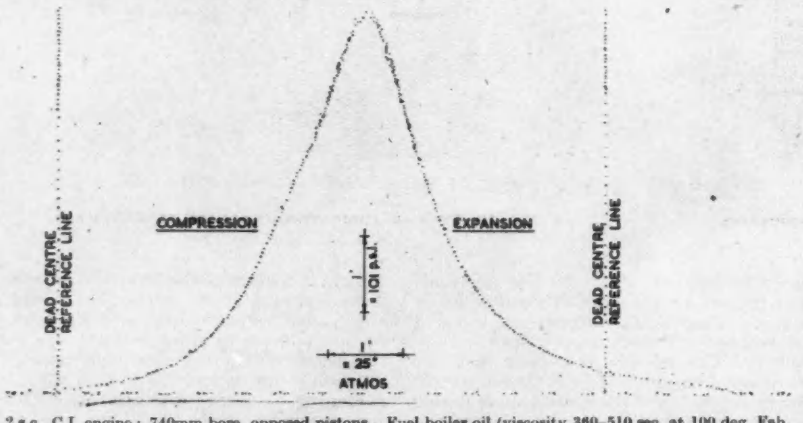
(ii) Effect of temperature, humidity and clamping upon the papers used for diagrams and tracings.

(iii) The human element in measurement.

Regarding the first item, the geometric characteristics of the springs and linkages between the indicator piston and spark point cause a slight deviation from linearity of the relation between pressure and spark-point travel. The maximum deviation observed is of the order of 5 lb per square inch on 1000 lb per square inch total, but the mean error is rarely greater than about 2 lb per square inch and no appreciable error is caused by the assumption of linearity, providing due allowance is made for zero frictional error if actual pressures are to be noted.

The second item can cause appreciable errors if the materials are not carefully chosen and used. Providing the black-faced diagram papers are folded truly and attached to the drum with care no noticeable distortion of the diagram will occur on removal. This paper is slightly susceptible to damp and it has been found advisable to make tracings on a plastic-base material as soon as possible after recording. As mutilation of the recorded diagram by lining-in tends to obliterate the spark holes (diameter about 0·002in), it has been the practice to trace the lines of holes on to an acetate-based plastic. This substance is impervious to moisture, has no "grain" and apparently a comparatively low thermal coefficient of expansion, but needs handling with care as folds or jagged edges readily initiate tears. It has been found that the use of a sharp, hard pencil enables clear lines to be drawn of thickness not greater than 0·002in.

In order to minimise the effect on the determination of mean pressure of the human element in measurement, care has been taken in the choice of methods. The overall error due to this cause may not be greater than the variation of ½ per cent observed when the mean figures for one set of diagrams are compared. Individual differences of up to 1 per cent may be expected on any one diagram, but these variations when averaged have not exceeded ½ per cent for the whole engine.



2 s.c., C.I. engine; 740mm bore, opposed pistons. Fuel-boiler oil (viscosity 360–510 sec. at 100 deg. Fah. Redwood No. 1). 100 r.p.m.

FIG. 13—TYPICAL INDICATOR DIAGRAM AT 100 R.P.M.

General Commentary

The approach to the problem of slow and medium-speed engine indication has been to produce a robust apparatus capable of giving consistently accurate results with a minimum of complication. In addition to the primary use for the measurement of indicated mean pressure the diagrams obtained are suitable for the study of combustion in the cylinder, the determination of forces on the crankshaft for torsional vibration calculations, and the investigation of the phenomena of gas flow, &c.

It may be felt that portions of the apparatus are unnecessarily complicated, but one major requirement was that the equipment must be readily adaptable for fitting at short notice to any make and type of slow or medium-speed marine oil engine with the minimum disturbance of test-bed or sea-trial routine and with limited labour. A simplified and more compact version of this apparatus will shortly be commercially available either complete or as an addition to existing Farnboro equipment. This will be marketed by Dobbie McInnes, Ltd., of 191, Broomloan Road, Govan, Glasgow, the manufacturers of the standard Farnboro equipment.

Future Developments

Present development consists of modifications to the electronic unit to permit the simultaneous recording of signals from all diaphragm units mounted on the cylinders of an engine. This will enable all cylinders to be indicated within the space of about one minute, with an additional time of three minutes for marking top centres and calibrations. The short space of time required for recording will reduce the possibility of power fluctuations vitiating the result (the present time for the eight cylinders of a slow-speed engine is twenty to thirty minutes) and will make it possible for the indicated power to be measured at sea during a run over a measured mile. Also being designed is a cylinder and piston assembly for the recording unit such that an extended scale of pressure is available for taking low-pressure diagrams of phenomena occurring in the cylinders while ports or valves are open and in manifolds, scavenge pumps, &c. The present pressure scale of these diagrams is about 7 lb per square inch per inch and cannot be increased without introducing unacceptable frictional effects. The objective is a scale of about 2 lb per square inch per inch free from appreciable frictional errors.

To obtain complete running records and to keep a check on the stability of test conditions it would be an advantage to have available a record of engine revolutions against time, and a simple apparatus could be built into the recording unit to record both revolutions and a timing trace on a suitable substance such as Teledeltos paper.

It has been suggested that this apparatus could be built into an engine as standard equipment in place of the normal indicating gear, if the difficulty of obtaining a supply of high-pressure gas could be eliminated. In oil-engined vessels a supply of starting air is available at a pressure of 350 lb to 400 lb per square inch and it should be possible to include in the recording unit a single-stage booster compressor of small capacity to build this up to the required 800 lb to 900 lb per square inch. The provision of suitably interconnected electrical circuits might eliminate the necessity for the hand-controlled gas valves, the build-up of pressure from the compressor causing the steady rise in pressure in the indicator pipelines.

As stated earlier, diagrams obtained at speeds

up to 1800 r.p.m. are remarkably clear and free from scatter, &c., and give no indication of "cut-off" at the maximum pressure. This cut-off would appear at much higher speeds because of the time necessary for the gas-filled thyratron valves to de-ionise before they could again be triggered. The accuracy of diagrams taken at this speed is the subject of an independent investigation and the prospects of developing a smaller unit capable of giving accurate diagrams at high speeds appear favourable.

Computation of Indicated M.E.P. Diagrams

Untouched photographic copies taken direct from typical Farnboro indicator diagrams obtained with the modified apparatus are shown in Figs. 12 and 13, the original diagrams consisting of thin sheets of special paper, black on one side, the various spark perforations appearing as bright points of light when the sheet is placed black side uppermost on an illuminated screen.

An examination of the prints will show the horizontal base line, located at atmospheric pressure; the diagram giving the relationship between pressure and degrees of crankshaft rotation, and the top centre line or dead-centre reference lines.

Since the paper is wrapped around the periphery of a drum rotating at crankshaft speed, it follows that the length of the diagram (14·385in for the indicator at present in use) is equivalent to 360 deg. of crankshaft rotation. This is in effect a time base when engine speed is taken into consideration.

The degree scale being linear the curve cannot be integrated directly to obtain mean effective pressure.

Two methods are available for the determination of this mean pressure:—

(1) "Longhand" method, the conversion of the diagram from a degree base to a stroke base followed by the measurement of area and hence summation of work done. (2) "Scale" method, the use of mathematical calculation to transfer mean ordinates on a pressure-volume or stroke diagram to equivalent ordinates on a degree base, these equivalent ordinates then being measured and their algebraic sum divided by the number of ordinates, giving the mean ordinate of pressure equal to that obtained from a pressure-volume diagram.

Both methods have been used for the measurement of diagrams and it has been found that method (2) shows the most consistent results, due to the lesser number of steps in the analysis. It is, moreover, considerably quicker.

The preliminary stages of the operation are common to both methods. The original diagram is placed, black side uppermost, on a "light box," consisting of a wooden box containing two 100W electric lamp bulbs and fitted with dull white reflecting surfaces, such that a brilliant and even illumination is provided over the whole area of a clear glass sheet of a size that pins may be used to fix the diagram. A piece of transparent plastic tracing material is pinned over the diagram. The diagram and the reference lines are then traced, using a pencil of 6H grade to maintain a line thickness of 0·004in to 0·002in and the position checked by observing that a marked change in spark hole brilliancy occurs when coincidence between hole and line is obtained. A constant error of 0·004in in height on one side of the diagram will produce an error in the final mean pressure of approaching ½ per cent. In the case of a diagram having two dead-centre reference lines, the dead-centre line is constructed exactly midway between them.

Method 1.—The piston displacements are drawn out for every 5 deg. of crank rotation, the base or equivalent-stroke scale being chosen so that stroke and diagram height are approximately equal. This precaution reduces the mean error in measurement. The diagram tracing is now superimposed on a transparent scale divided in degrees to suit the indicator drum circumference. Accuracy is all important and precautions must be taken to eliminate parallax error by having the scale arranged so that the graduations are on the top surface and next to the tracing. The diagram height at each 5 deg. division is next transferred to the stroke base already prepared and the pressure-volume diagram built up. The area of this diagram is measured. For the latter purpose the mid-ordinate method has proved the easiest and most accurate, forty-eight ordinates being satisfactory.

Method 2.—A transparent scale (or accurate tracing) is prepared from the calculation of the equivalent ordinates referred to earlier and the tracing superimposed upon it, due precautions being taken.

The heights of the equivalent ordinates are then measured directly and the mean ordinate, and hence mean pressure, is calculated as follows, the equivalent of fifty mid-ordinates on a pressure-volume diagram being convenient and sufficiently accurate:—

$$\text{Mean ordinate} = \frac{\text{(Sum of equivalent ordinates on expansion side of top centre line) minus (sum of equivalent ordinates on compression side)}}{50}$$

Transparent Scales.—Transparent scales used for the setting out of ordinates and for the measurement of heights should be of matured Perspex, cut from the centre of a manufactured sheet. This substance is reported to have a lower and more uniform coefficient of thermal expansion than the majority of the more common transparent plastics. It is possible to divide such scales with an accuracy of ±0·002in and line thickness can be less than 0·004in. These scales should be constructed so that the scribed lines are next to the tracing when in use, eliminating parallax error. Any one special scale for Method (2) can only be used for engines having the same ratio of stroke to connecting-rod length as that for which it was constructed. A convenient scale for measuring the height of ordinates has been constructed from a rectangular bar of Perspex 1½in × ⅛in in section, having graduations of 1in, ½in, $^1/_{10}$in and $^1/_{50}$in scribed on the underside. In use measurements are read through the scale, not on the edge, and no difficulty is experienced in reading to 0·01in. This accuracy has proved quite satisfactory.

Exhibition of Physics in Industry

An exhibition on the theme "Physics in the Transport, Shipbuilding and Engineering Industries" was held from June 24th to 28th at the Royal Technical College, Glasgow. It was organised by the Institute of Physics, to coincide with the conference on the same subject.

Within this context there emerged two clear categories of exhibits. There were those dealing with the provision of instruments to industry and those dealing with physical research and its application, or with the exploration of industrial processes.

Many of the exhibits in the first category were, of course, familiar, though none the less valuable. Magnetic crack detectors, a.c. and d.c. meters, controllers, temperature indicators and recorders, and ultra-violet light equipment were all well represented. There were several new or comparatively new instruments, however, that merited interest and respect. Metropolitan-Vickers Electrical Company, Ltd., showed a 55kV electron microscope, which has been designed primarily as an inexpensive instrument in factory or laboratory, where it can be connected to standard factory electrical mains. It provides magnifications up to 1200 with a resolution "better than 100Å." Some examples of its work, showing pearlite structure in steel, taken from preshadowed replicas, were certainly impressive.

Another unfamiliar exhibit was an ultrasonic instrument designed for measuring the thickness of metal and other sheets when only one side is accessible. Dawe Instrument, Ltd., showed this instrument, which is the British version of the "Audigauge," manufactured in the U.S.A. It is claimed to give an accuracy of plus or minus 3 per cent over a range of $\frac{1}{32}$in to 12in thickness on steel, brass, aluminium, copper, nickel, glass, and some plastics. It operates through a 1¼in. diameter probe, applied to the surface of the sheet through a lubricant, similarly to the probes of the more familiar ultrasonic flaw detectors. An interesting comparison with this instrument was provided on the stand of the British Iron and Steel Research Association, where an instrument designed for a more limited purpose was on view. It was a plate thickness meter originally developed for corrosion investigations, which uses the total magnetic flux at saturation as a measure of thickness. It has a range of 0 to 0·25in, with an accuracy similar to that of the Dawe instrument.

In the second category, the application of physical research to industry, the Department of Scientific and Industrial Research had some interesting items on show. The Mechanical Engineering Research Organisation, for example, demonstrated its work on extrusion and had a small extrusion press on its stand. The purpose of this work is to elucidate the principles governing the flow of extruded metals. Specimens were available on the stand to show how grids inscribed on the faces of split slugs had given valuable information in determining the effects of slug thickness, punch speed, tool profile, &c., on the cold extrusion of aluminium and other metals.

In the same category, perhaps, came the ultrasonic phenomena demonstrations by Mullard, Ltd. An underwater demonstration showed how high-intensity ultrasonic waves passing through a liquid cause growth and collapse of voids round any nuclei in the liquid, and give rise to cavitation. This has been applied in small-scale ultrasonic soldering baths for some time, but now it can be, and is being, applied to larger apparatus, as shown by this firm. A Mullard ultrasonic soldering iron was also demonstrated.

Interesting instruments in the same category were shown by Imperial Chemical Industries, Ltd., Nobel Division Research Department. One instrument was a counter timer, designed originally for the routine testing of delay detonators, but adaptable for many purposes. It uses the new Ericsson "Dekatron" counting tubes and has a crystal-controlled oscillator to maintain an accuracy of 1 in 10,000. The starting and stopping circuits are designed to operate from a variety of signals, and the model shown covered the range 0 to 99·999 seconds in milliseconds. The instrument measures only 17in by 11in by 9in, which may recommend it for process time measurements as well as for research work.

Lastly, we may mention an item of a purely exploratory nature—the demonstration by B.I.S.R.A. of stereoscopic, high-speed cinephotography in the blast-furnace, whereby visitors were able to see stereoscopic films (using a polarised viewer) taken at 3000 frames per second through specially built tuyere windows on various blast-furnaces. By an ingenious analysis technique, also demonstrated, it is possible to plot the range and paths of individual particles of ore and coke in the blast before the tuyeres. Already it has been found possible, it was stated, to discover the size of the cavity in front of the tuyere. In time, it is hoped that this technique may contribute to the answer to the centuries-old question whether there is a "deadman" of unburnt material in the middle of the blast-furnace. A definite answer might presage important changes in the design criteria now accepted.

C. T. R. Wilson and the Cloud Chamber.—Professor C. T. R. Wilson's original work in the development of apparatus for producing a cloud by adiabatic expansion forms the subject of an excellent monograph, the fourth in a series published by the Cambridge Instrument Company, Ltd., 13, Grosvenor Place, London, S.W.1. The cloud chamber was devised by Professor Wilson for rendering visible and photographing the tracks of ionising particles.

British Locomotive Performance and Efficiency Tests

By O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E.

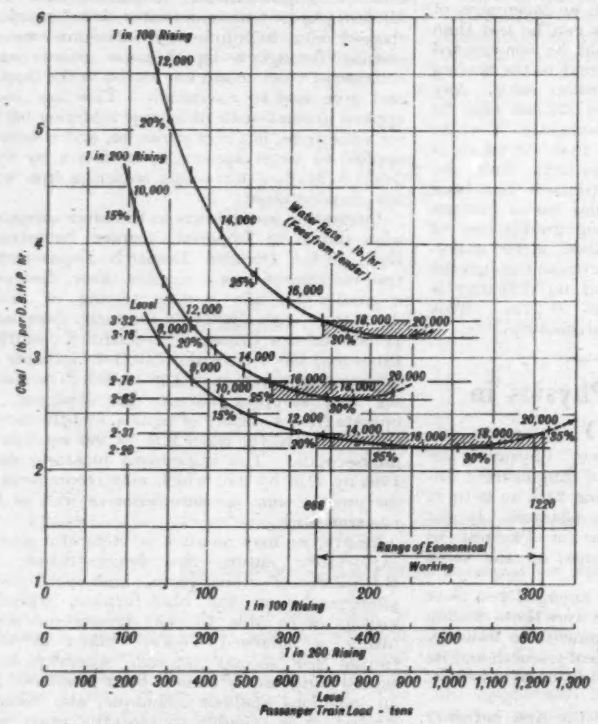
No. IV—(*Concluded from page 31, July 4th*)

In the previous articles on this subject, reviewing the Bulletins 1, 2 *and* 3 *published by the Railway Executive, reference was made to some general characteristics of the locomotives under observation, to the testing procedure, both in the stationary plants and on the road, and details were included of evaporation rates with different classes of coal. In Part IV herewith, details are given of the drawbar characteristics, and of the indicated characteristics where available, and how these results are presented in such a way as to make clear to the operating department the cost, in coal consumption, of running at various speeds with loads covering the normal range of traffic. Coal consumption in both freight and passenger service is given for each locomotive.*

Economical Running Conditions

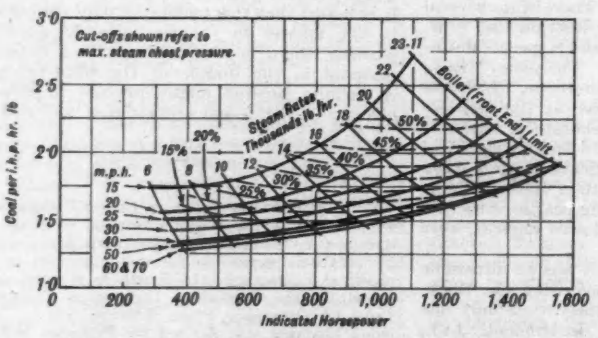
THE Bulletins 1 and 2 contain some examples worked out to show how the performance graphs proper can be utilised for establishing load and speed relations in the operating of both passenger and goods traffic. The example reproduced in Fig. 12 is taken from the "B1" tests, as this shows conditions worked out for three different gradients, each with a sustained speed of 50 m.p.h. There are three horizontal scales, corresponding to level, 1 in 200 and 1 in 100 respectively, and it will be seen that for minimum coal consumption per drawbar horsepower-hour the loads should be 670 tons to 1240 tons on the level, 300 tons to 400 tons for 1 in 200 rising gradient, and 175 tons to 225 tons for a 1 in 100 rise. The significant point will be noted that with a "B1" engine it uses considerably more coal per drawbar horsepower-hour to run a 300-ton train at 50 m.p.h. on the level than it does to run a train of 1000 tons—3·39 lb, against 2·39 lb. Expressing the difference in terms of the same load, 300 tons, it is more economical to run faster on the level, since the coal per drawbar horsepower-hour at 70 m.p.h. is only 2·8 lb. The coal consumptions per ton-mile are 0·061 lb at 50 m.p.h. and 0·086 lb at 70 m.p.h., so that over any period of time the actual coal burned with a 300-ton train is no more at 70 m.p.h. than at 50 m.p.h. In such conditions acceleration of train schedules could be effected without any increase in coal consumption.

Turning now to the London Midland Class "4" 2–6–0, the performance graphs as set out in Bulletin No. 3 reveal rather different characteristics from those of the 4–6–0s. Fig. 9 has already been commented upon as showing a very "flat" curve of coal per drawbar horsepower-hour plotted against drawbar horsepower; in contrast the Class "4" 2–6–0 shows a more limited range of economical working. A table has been reproduced showing coal consumption for the three classes of coal, and four varieties of road conditions to indicate the general performance of this engine, but some further reference to the graphs will be of interest. In passenger service on level track, for example, the curve of coal per drawbar horsepower-hour at 60 m.p.h. drops steeply from no less than 4·7 lb with a train of 150 tons to 3·2 lb at 300 tons, rising again to 3·5 lb with 450 tons. These engines are intended for light passenger work of an intermediate kind, and this relatively high coal consumption at low output must be noted. At 50 m.p.h. the working


1 in 100 Rising
1 in 200 Rising
Level
Water Rate - lb./hr. (Feed from Tender)
Range of Economical Working
Coal - lb. per D.B.H.P. hr.
Passenger Train Load - tons

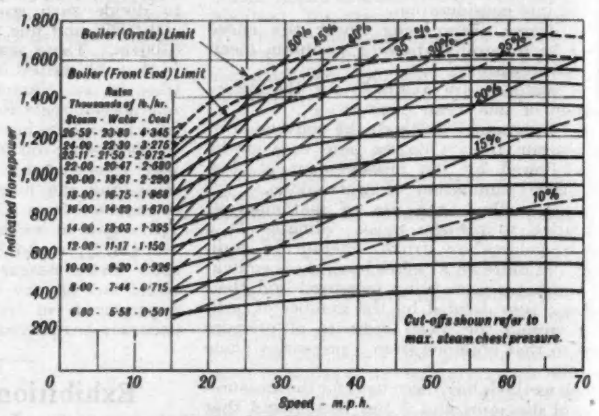
South Kirkby coal, 138,000 B.Th.U./lb. As fired

FIG. 12—RANGE OF ECONOMICAL WORKING AT 50 M.P.H. "B1" LOCOMOTIVE


Cut-offs shown refer to max. steam chest pressure.
Boiler (Front End) Limit
Steam Rates Thousands lb./hr.
Coal per i.h.p. hr. lb
Indicated Horsepower

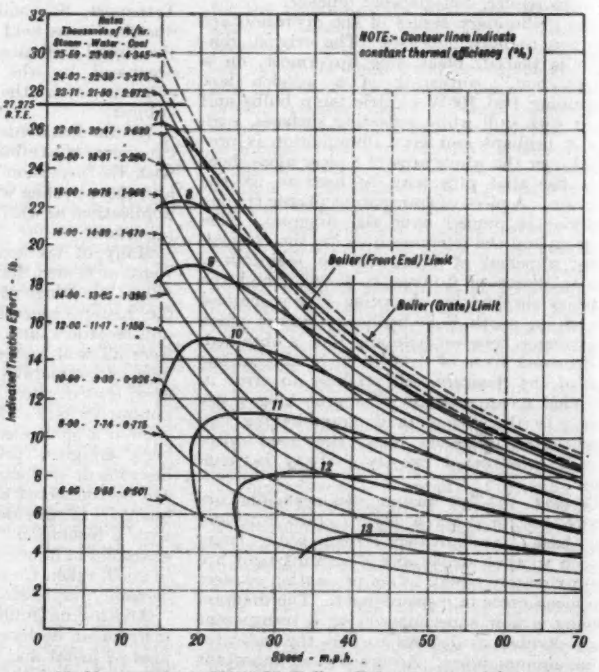
Markham coal, 14,330 B.Th.U./lb. Exhaust steam injector

FIG. 13—COAL CONSUMPTION AND INDICATED HORSEPOWER "HALL" LOCOMOTIVE


Boiler (Grate) Limit
Boiler (Front End) Limit
Rates Thousands of lb./hr.
Steam - Water - Coal
Cut-offs shown refer to max. steam chest pressure.
Indicated Horsepower
Speed - m.p.h.

Markham coal. 14,330 B.Th.U./lb. Exhaust steam injector

FIG. 14—INDICATED CHARACTERISTICS OF "HALL" LOCOMOTIVE


NOTE:- Contour lines indicate constant thermal efficiency (%)
Boiler (Front End) Limit
Boiler (Grate) Limit
Indicated Tractive Effort - lb.
Speed - m.p.h.

Markham coal, 14,330 B.Th.U./lb. Exhaust steam injector
Indicated tractive effort—16 × 1000

FIG. 15—OVERALL EFFICIENCY RELATED TO CYLINDERS

L.M. Class "4" 2–6–0—Coal Consumption Data

Service	Gradient	Load, tons	Speed, m.p.h.	Coal consumption, lb					
				Blidworth		Bedwas		Lillieshall	
				Per ton-mile	Per d.h.p.-hour	Per ton-mile	Per d.h.p.-hour	Per ton-mile	Per d.h.p.-hour
Passenger	Level	200	50	0·088	4·15	0·08	4·0	0·10	4·6
		200	60	0·110	3·9	0·095	3·8	0·12	4·2
		300	50	0·070	3·4	0·067	3·05	0·08	3·7
		300	60	0·089	3·2	0·08	2·9	0·10	3·55
		400	50	0·062	2·95	0·055	2·6	0·07	3·3
		400	60	0·090	3·3	0·08	2·9	0·105	3·5
Passenger	1 in 200 rising ...	200	30	0·145	2·5	0·13	2·3	0·155	2·75
		200	40	0·155	2·51	0·137	2·3	0·170	2·75
		200	50	0·190	2·9	0·168	2·5	0·20	3·0
		300	30	0·125	2·3	0·11	2·1	0·133	2·6
		300	40	0·145	2·55	0·125	2·3	0·155	2·8
		400	30	0·115	2·25	0·10	2·0	0·125	2·5
Freight	Level	500	20	0·04	3·05	0·04	2·8	0·05	3·4
		500	40	0·065	2·5	0·06	2·2	0·07	2·75
		900	20	0·033	2·5	0·032	2·3	0·038	2·7
		900	30	0·042	2·3	0·037	2·05	0·05	2·5
		900	40	0·075	3·0	0·070	2·7	0·082	3·2
Freight	1 in 200 rising ...	350	40	0·19	2·0	0·170	2·7	0·21	3·2
		600	20	0·11	2·25	0·10	2·0	0·125	2·5
		600	30	0·16	3·0	0·133	2·6	0·170	3·1
		900	20	0·14	2·9	0·120	2·5	0·15	3·1

of a train of 150 tons on the level needs 5·2 lb of coal per drawbar horsepower-hour. As the steam rate rises the efficiency increases rapidly, and the figures quoted in the table for a 300-ton passenger train climbing a gradient of 1 in 200 are excellent, varying from 2·1 lb to 2·8 lb of coal per drawbar horsepower-hour. Although the curves of coal per ton-mile and coal per drawbar horsepower-hour tend to rise rapidly again from the regions of maximum economy, the coal per drawbar horsepower-hour does not greatly exceed 3 lb, as the "front end limit" of the boiler is reached.

Indicated Characteristics

To those who have, in the past, tried to piece together the performance of locomotives from the rather sketchy details published of earlier tests, the completeness of the information contained in these three bulletins will be a delight. Fig. 14 herewith shows, for example, not just a few isolated examples of maximum indicated horsepower, but the complete family of characteristic curves, related also to the curves of power output on lines of constant cut-off. These curves should be studied in conjunction with the indicator diagrams, of which a selection are reproduced herewith. The valve motion is modified a little from the historic Churchward long-travel layout which was standard on the Great Western two-cylinder engines of all outside-cylinder types for many years. The high-superheat "Halls" have 6¼in travel in full gear and a steam lap of 1¼in, whereas the original design provided 6¼in travel and a lap of 1⅛in. In full gear the lead is negative, and averages 0·18in; it changes to a positive value about 60 per cent cut-off, and thereafter rises to about 0·10in at 40 per cent, and to 0·16in on an average, at 20 per cent. The frictional horsepower may be seen from the table below.

The values of 490 frictional horsepower at 60 m.p.h. appear to be a little on the high side for a modern locomotive; it remains fairly constant over the steaming rates examined, and is 460 at an evaporation of 12,000. By comparison, some figures that were published a considerable time ago for the "Castle" class locomotives showed frictional horsepower values of about 350 at 65 m.p.h. The "Hall" value, at 65 m.p.h., and an evaporation of 22,000 lb per hour, is no less than 580.

As the drawbar characteristics have been presented in such a way as to render them immediately applicable to traffic conditions, it is probable, however, that allowance has been made for the retarding effect of a head wind on the locomotive and tender of, say, 10 to 15 m.p.h., to cover average conditions, and that the effects of this are included in the "frictional" horsepower. The result would therefore be greater than the plain difference between indicated horsepower and drawbar horsepower as measured in still air, or on one of the stationary testing plants. At the time of the "Castle" tests in 1924, the wind may have been favourable to the locomotive. Such points as allowances for wind resistances may be discussed in the further bulletin promised, giving a critical commentary on some of the results.

Some typical figures for the London Midland Class "4" 2–6–0 are given in a further table:

Blidworth Coal

Speed, m.p.h.	16,000 lb of steam per hour		
	I.h.p.	D.h.p.	F.h.p.
20	910	860	50
30	1010	910	100
40	1055	890	165
50	1075	825	250
60	1080	740	340

Horsepower Values, "Hall" Class Engine (Markham Coal)

Speed (m.p.h.)	22,000 lb of steam per hour			16,000 lb of steam per hour		
	I.h.p.	D.h.p.	F.h.p.	I.h.p.	D.h.p.	F.h.p.
30	1370	1190	180	1000	815	185
45	1470	1170	300	1080	770	310
60	1480	990	490	1090	600	490

The frictional horsepower at 60 m.p.h., considered in relation to total loaded weight of engine and tender is less than that of the "Hall": 340 for a total weight of 99½ tons, against 490 for a total weight of 123 tons—3·42 h.p. per ton, against 3·98.

In Fig. 13 may be studied the excellent indicated characteristics of the "Hall" plotted against the coal per indicated horsepower-hour, and it will be seen that at 70 m.p.h. and an indicated horsepower of 1400, the coal per indicated horsepower-hour is no more than 1·75 lb, using Markham coal. This output requires the use of 25 per cent cut-off and full regulator, and represents a cylinder thermal efficiency of 13·5 per cent, and the overall efficiency, referred to the cylinders, is about 10 per cent. In view of the rapidly increasing frictional horsepower in the 55–65 m.p.h. speed range, established in this report, it might however, be imagined that speeds exceeding 60 m.p.h. would be rare with the "Hall" class engines in every-day service. Actually, the author has, in his personal records, many examples of very free running in ordinary services when the enginemen were unaware any detailed notes were being taken of the speed. With engines of the high-superheat series the following may be quoted, all well sustained speeds on level track:—

Engine No.	Load, tons	Sustained speed, m.p.h.
6971	450	66
6972	420	69
6986	450	68

From graphs in Bulletin No. 1, (see Fig. 15) these efforts appear to be close to the "front-end" limit of the boiler. On other occasions engines of this same high superheat series have

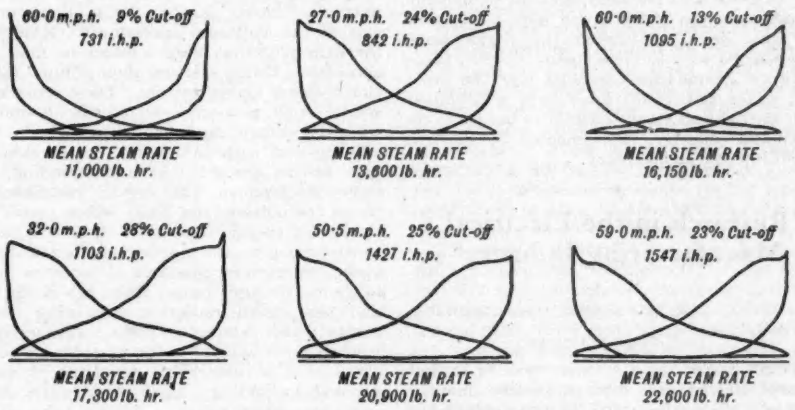


FIG. 16—SELECTION OF INDICATOR DIAGRAMS

run freely up to 77 and 78 m.p.h. on favourable stretches of the line.

To conclude, the bulletins show that the "Hall" and the "B1" were very evenly matched at low speed, and the general performance of both engines can be considered as excellent; at higher speeds, the advantage, in the important items of coal per drawbar horsepower-hour and coal per ton-mile, seems to lie with the "B1," though it should be emphasised once again that No. 61353 was far from a standard example of her class so far as balancing was concerned. To complete the picture tests were needed of the same two classes in a run-down condition, and it would be fairest if the "B1" chosen were one taken straight out of traffic, even though she might prove even more awkward to test from the oscillation point of view than the London Midland Class "4," 2–6–0 actually tested at Swindon. The latter engine seemed efficient at medium power output, but in view of the large amount of light work that has to be performed on British Railways, for which these engines are well suited from the tractive effort point of view, there would seem to be room for improvement in the low power characteristics, as at present represented by coal consumption rates in excess of 4 lb per drawbar horsepower-hour.

In the second instalment of this article, published in THE ENGINEER for June 20, 1952, a note was included beneath the table on page 818 that the maximum steaming capacity of the "B1" boiler was not determined. It was, in fact, determined with South Kirkby coal when using the live steam injector only. Feed water rates up to 25,000 lb per hour were attained. The firing rate was 192 lb per square foot of grate area per hour, and the equivalent evaporation was 34,285 lb per hour. This was a "grate limit." Although this performance was reached with the live steam injector, there are good grounds for assuming that the same feed water rate could have been maintained with the exhaust steam injector in use up to its maximum capacity, supplemented by the live steam injector as necessary.

Research in the Electrical Manufacturing Industry*

No. I

By DR. K. J. R. WILKINSON, D.Sc., M.I.E.E.

The Basic Sciences

EVERY industrialist is concerned to exploit natural effects in one form or another, but the laws of nature which are the province of the electrical manufacturer are both numerous and varied. The laws he must respect can be classed either as profoundly simple, straightforwardly complicated, or plainly abstruse. They appear simple where they describe the effects of electricity in engineering terms; thanks to the work of those outstanding physicists in the nineteenth century, who took this subject in their stride, there can be few activities where a far-reaching knowledge is to be stated with such clarity, brevity and comprehensiveness as in electrical science. For example, it is easy to imagine how very little advance could have been made in electrical engineering if these rules had not been recognised and development had rested solely, as in so many of the older industries, on the intuitive approach of the craftsman.

But the manufacturer cannot get by with just the elements of electrical science; his products use a great variety of materials, and they mostly embody processes or circuits which are complicated, or non-linear, or show transient effects not easy to predict. His particular world, therefore, lies somewhere between basic concepts which are easier to state than to comprehend, and his products, whose physical form often belies the simplicity of the concepts they embody. Though he is occupied with essentially practical things—very much as in any other industry—his concern with electricity, and with the wide range of its applications, ensures that the electrical manufacturer shall have a predominately scientific outlook. Thus he is concerned first with a basic understanding of the engineering sciences; not only electromagnetism and circuit theory, but also the theory of machines and of structures, thermodynamics, the physics of solids, and the properties of gases. To these basic studies he adds a leavening of metallurgy, of the chemistry and physical chemistry of insulations, of aerodynamics, of the physics of surface behaviour, of acoustics, and of the properties of radiation—ranging from gamma rays through the visible spectrum and heat to radio waves.

Imposing as this list may be, each item is a study in itself, if not a whole series of studies. For example, the physics of solids can be held to include ferromagnetism, the theory of conduction in metals and in semi-conductors, the theory of dielectrics, and to have a bearing upon thermionic emission, and upon field emission—all of them subjects of great importance to electrical engineering.

The Range of Products

If we think first of products, it is natural to start with electrical generators, transformers and circuit-breakers, and then to appreciate that examples of all these are applied in such diverse ways that at one extreme they handle a hundred megavolt-amps or so, and at the other perhaps a micro-micro volt-amp. A power range of about 10^{20}; or the number of electron charges in 16 coulombs!

Many of the lesser known effects which are of increasing importance to the electrical industry first see their application at medium or low powers; for this reason research is naturally active at this fertile light-current end of the volt-amp spectrum.† It is here, for example, that semi-conductors first gain acceptance before starting their gradual migration towards higher powers. These remarkable solids, with properties so closely bound up with the energy states of electron shells, with valency and with the crystal lattice, are still only at the threshold of understanding, and their development into crystal rectifiers and plates exhibiting the Hall effect, and into photo and thermo-conductive devices is to-day contributing to the history of electrical progress. Continuing this tour of products in the medium volt-amp range, there are X-ray sets and the varied radiation measuring instruments which belong to them. Among these instruments the unassuming portable ionisation chamber is a remarkable development, for it succeeds in holding a small electrostatic charge—a few micro-micro coulombs—for many hours, or until this charge is neutralised by ionisation from the radiation being measured. In terms of sheer insulation it is outstanding, for its natural leakage at about 100V must be less than 10^{-16} amperes.

From the X-ray set we pass to those strange children of this decade, particle accelerators, some with circular and others with linear orbits. The accelerators with circular ones serve to combine both high-power engineering and fairly low power—but still quite lethal—radiation outputs. Those with linear orbits, though at rather lower MeV, are much more powerful in output radiation and are one of the most effective contributions this country has made to sources of therapeutic radiation.

Since these linear accelerators use magnetrons we come naturally to radar, a complexity of engineering which has also to handle power—this time pulsed radio waves—at very widely differing levels; a difference brought about quite naturally by the inverse square law which, acting inexorably as the beam travels both ways, leads to a reflected signal whose intensity varies with the radiated one as the inverse fourth power of the distance to the target.

Just as there are valves working in the light current region, so there are rectifiers and grid-controlled rectifiers for operation at substantial levels of power. In a recent installation eight ignitrons acting together will pass one complete cycle of current lasting $^1/_{50}$ second. They serve to discharge and then to recharge on the reverse swing a large condenser, by connecting it to the inductive field winding of a synchrotron. In doing this the ignitrons switch 30,000kVA.

The Research Effort

These very different electrical products, which range widely over the field of physics, call for at least two interests of present importance. One of these lies in the continuing evolution, application and understanding of the products themselves, and the other in new materials which these products might embody. Taken together these interests form a mixture of inquisitiveness and creative engineering which it is sometimes difficult to decide whether to call research or development; but by whichever name it is known, the underlying endeavour is woven very closely into the fabric of the electrical manufacturing industry.

For the present purpose we shall include as research those efforts which result in establishing something new, whether it is an electrical component, a material, a process of manufacture, a technique of measurement, or a method of analysing a problem. Such a versatile field of interest cannot be rigidly defined, and while it excludes the majority of manufactured products—those which are the outcome of normal design procedure—it must include a great deal of apparently unproductive effort. Research in this sense of the word is not always confined within a research laboratory (though it will frequently stem from one), and it may sometimes lie entirely within an engineering group.

It is estimated that in the electrical manufacturing industry the effort devoted to research of this nature represents about 2 or 3 per cent of the turnover and may occupy some 20 per cent of the professionally qualified staff, but these are rather general figures depending considerably upon the character of the product with which the research is concerned.

Now, as to the aims of research. These are not always predictable but the general trends of successful work can be seen as gains either to our understanding of a new field of interest, or to the ability to measure some elusive effect, or in achieving some new engineering device. Often they are a combination of all three of these things, for unless an effect can be measured it cannot be completely understood, and no successful development can result without both measurement and understanding. But this apart, it is necessary if we are to appreciate the general nature and wide scope of this research activity to give at least a passing reference to specific examples. In selecting these brief illustrations it will be remembered that they should have a bearing upon power engineering—for that is the interest of this conference—and in presenting them they will be grouped conveniently under the headings Understanding, Measurement and Development, as representatives of these three somewhat arbitrary stages in the evolution of an electrical component.

Understanding

Let us start by considering some researches which achieve an improved understanding.

Magnetic Properties of Sheet Steel.—The foundations of the electrical industry rest upon the properties by which some materials conduct electricity, some insulate, and others are magnetic, and it is a very fortunate circumstance that a common element should exhibit the remarkable and complex properties of ferromagnetism. The mechanisms underlying this property are only now becoming clearer to us, thanks largely to the work of scientists like Bitter, who by clearly demonstrating the physical existence of domains has given new impetus to the work of understanding this subject. But between the fundamental concepts of the domain theory and the properties of electrical sheet steel as used in engineering there lies a very great deal of metallurgical understanding, of steel making effort and of measuring skill. It is known that by a carefully controlled schedule of cold reduction and

* Abstracts. Paper presented on behalf of the British Electrical and Allied Manufacturers Association, at the British Electrical Power Convention, Bournemouth, June 17, 1952.

† A devious metaphor—but so is the subject.

heat treatment, combined with care in the choice of ores and preparation of ingots, silicon steel strip can be cold-rolled to give lower hysteresis losses at high flux densities than corresponding hot-rolled material, and that a factor contributing to this improvement is the degree to which the silicon steel crystal-structure can be aligned or oriented within the sheet. But so many confusing and possibly important factors can intervene—such as the presence of some trace element—that a careful and systematic research is essential before conditions necessary for the production of cold-rolled strip can be specified with certainty.

A complicated research into the effect of composition and of rolling and heat treatments upon crystal orientation and electrical losses is being undertaken by the electrical manufacturing industry in this country. Before attacking the factors which control orientation it has been necessary to study the physical metallurgy of silicon steel, and some results of this research include two separate methods of portraying the degree of crystal orientation; one by reflected light, and the other by an X-ray camera which makes a direct chart of texture or crystal orientation. In the same field of research, methods have been devised for measuring electrical losses at high flux densities on quite small amounts of material. In parallel with this work, the electrical industry has succeeded in growing crystals of silicon steel 30in to 40in in length, and some 3in wide,‡ for use in fundamental work on the magnetic properties of this material.

The Theory of Electrical Machines.—Within the last twenty or thirty years the number of possible forms which can be assumed by the rotating electrical machine—each with its own peculiar characteristics and its own appropriate application—has reached a bewildering total. It is therefore both natural and desirable that there should be a search, in the tradition of those physicists who seek a unified field theory, for a common basis of machine analysis; an effort to reduce the basic features of design to some uniformity.

It has been general practice for each machine to be considered as a member of its own type, but the advantages of a unified analytical treatment are immense. For instance, when this idea was applied in Britain to the analysis of polyphase commutator machines,[1] the common principle of an "injected" voltage made the analysis of even the most difficult relatively simple.

A concept embracing a wider field is based on the important work of Park in America, published in 1928. Park's contribution in itself had nothing to do with the unification of electrical machine theory; it was concerned with the definition of an ideal synchronous machine, and developed its equations of performance in terms of what are now called "two-axis quantities." These are fictitious voltages and currents mathematically related to the physical quantities, but they are such that the resulting differential equations are simplified to the extent of being manageable.

Some years later another American, Kron, showed that Park's two-axis concept forms a fundamental machine from which nearly all the others can be derived. He found that the fundamental equations in his unified theory could best be obtained and expressed in terms of tensor analysis; furthermore, they covered all types of electric machine without exception and proved to be identically the equations of electro-dynamics.

The mathematics employed was too advanced for all but a few engineers specialising in electrical machines and this led Kron quite recently to formulate his generalisation in terms of equivalent circuits comprehensible without advanced mathematics. Apart from the fact that equivalent circuits are a well established device in machine analysis, the steadily increasing use of network analysers makes this an important development. Kron's techniques—evolved from tensor analysis—for establishing the equations of performance of individual machines can be explained, for single machines, as distinct from systems of interconnected machines, without introducing tensors[2], and this simpler British approach appeals to a wider circle of engineers.

Another important aspect of progress in understanding is the possibility of a more scientific approach to problems in electric machine design formerly treated empirically and somewhat unsatisfactorily. For instance, certain high frequency generators use the principle of superposing a sinusoidally distributed flux density on a unidirectional one by suitable slotting at the airgap. Dr. F. W. Carter by a mathematical analysis derived the ratio of pulsating flux to total flux, and this result has been used to provide a better theory for these generators.[3] The same theory has also been applied to slot-ripple problems such as voltage waveform, surface losses and damper winding losses in generators and motors of normal frequency.

Similarly, the appearance of industrial eddy-current machines such as brakes and couplings necessitated an analysis of these machines based on field theory—an analysis subsequently applied with success to some of the various eddy current problems encountered in large a.c. machines.

The Network Analyser.—From one point of view the network analyser is a measuring instrument, but in the wider sense it is a powerful contributor to our understanding of what would

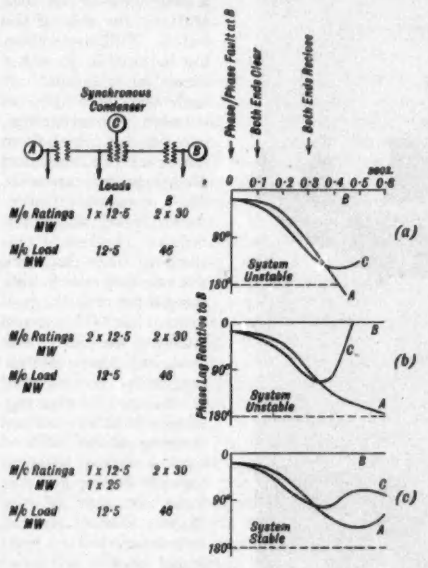


FIG. 1

otherwise be an immensely complicated subject. The system engineer cannot measure his quantities directly for they may not exist, as he must reckon at least a number of years ahead. He will be interested in factors such as generating costs, transmission losses, and system stability. His study will generally include a load balance using the complete proposed system to determine the voltages, currents, power and *VAR* flows to meet a given allocation of generating plant and loads. If necessary these distributions will be varied by changing taps on transformers, and by adding either reactors, capacitors, synchronous condensers, or phase-shifting transformers. It will then be necessary to repeat the load balance when some of the system is out of service, and this should, of course, include the most heavily loaded line. If conditions in the steady system are still satisfactory he will examine whether stability is maintained during a transient fault, imagined to be so placed that it causes interruption of a strategic circuit. With a true model network, fault currents and voltages are readily available, and to these it is necessary to add performance times of the protective gear and circuit breakers together with the inertia constants of the generators. Fig. 1 shows that a number of studies may be necessary before satisfactory conditions can be assured. Thus in diagrams (*a*) and (*b*) the inertia of machines at *A* is insufficient to prevent too great a slowing down (with respect to *B*). In diagram (*c*), *A* has sufficient machine inertia to delay the slowing process, so that when the tie between *A* and *B* and *C* is restored at 0·3 seconds, the phase difference is small enough to ensure a sufficient synchronising torque to lead to stability.

‡ Shown at the Physical Society Exhibition, April, 1951, by Metropolitan Vickers-Electrical Company, Ltd.

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[1] *Polyphase Commutator Machines*, Adkins and Gibbs, Cambridge University Press. 1951.

[2] "Modern Approach to Electrical Machine Analysis," W. J. Gibbs, THE ENGINEER. A series, October-November, 1951.

[3] "High Frequency Alternators," J. H. Walker, *Journal, I.E.E.*, Part II, Vol. 93, page 67, 1946.

(To be continued)

Change of Frequency on Southern Region Electrified System

THE announcement of the change of frequency scheme on the Southern Region's electrified system recalls the fact that the Western suburban section, which was electrified in 1915, was supplied with power from the railway's power station at Durnsford Road, Wimbledon. Mainly because of the better performance in those days of rotary converters supplied at 25 cycles per second, this frequency was chosen and current was distributed to manually-operated rotary converter substations by 11kV cables. This policy was maintained when the Central and Eastern suburban sections were equipped, but in this case power was obtained from 25 c/s plant at Deptford power station, now under the ownership of the British Electricity Authority. A total of forty-six rotary converter substations continuously manned are thus, at the present time, operating on a 25 c/s supply.

With the advent of the mercury-arc rectifier this restriction of frequency no longer applies. The plant at Durnsford Road power station is nearing the end of its life and it has been decided not to replace it. Similarly, the B.E.A.'s 25 c/s power station equipment needs replacement. After consideration of various alternatives, the Railway Executive, in November, 1950, authorised a scheme for the replacement of the existing 25 c/s, 11kV power supply system by a 50 c/s equipment.

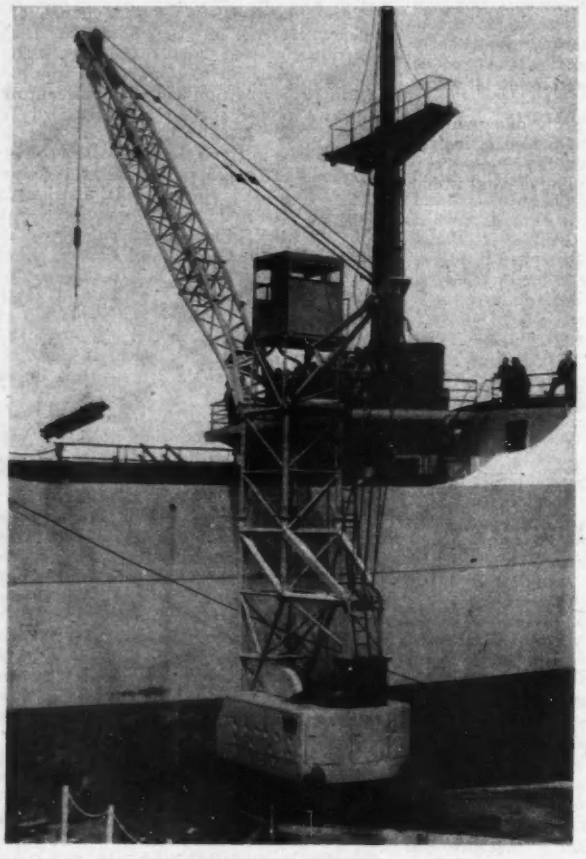
The electric power for the new installation will be drawn from the National Grid at 50 c/s and will feed seventy-two remotely controlled substations, including over 300MW of mercury arc rectifiers, three remotely controlled switching stations and sixty-seven remotely controlled track paralleling huts. The distribution system connecting the seventy-two rectifier substations and three switching stations with the Grid will comprise some 300 feeder miles of new 33kV oil-filled cable. Pilot cables will likewise be installed with the power cables, for protection purposes and for remote control from three new control stations of the substations, switching stations and track paralleling huts. Four 45MVA transformers will be employed to step down the voltage of a 66kV supply from the British Electricity Authority's Deptford East power station to 33kV. Supply will also be taken from the British Electricity Authority at four supply points at 33kV.

The new installation, for which orders were placed during the past year, will have a considerably increased plant capacity compared with the existing installation and this will enable the train service to be augmented, the length of the suburban trains increased from eight to ten cars, and the acceleration of the trains improved.

THE LATE MR. C. LESLIE FRY.—It is with regret that we have learned of the death of Mr. C. Leslie Fry, which occurred on Thursday, June 26th, while on holiday in the Scilly Isles. Mr. Fry, who was fifty-two years of age, was a local director of Thomas W. Ward, Ltd., and had completed thirty-eight years of service with the company. In addition, he was joint managing director of Low Moor Best Yorkshire Iron, Ltd., joint assistant managing director of the Wolverhampton Steel and Iron Company (1946), Ltd., and a director of Birchley Rolling Mills, Ltd.

A Mobile Cargo Crane

THE new Coles mobile cargo crane which has been produced by Steels Engineering Products, Ltd., Crown Works, Sunderland, has been specially designed by the company in an effort to solve some of the many problems set by the need for modernisation of cargo handling plant to speed up the turn round of shipping in our ports. Practical trials of the prototype crane were arranged and took place at Sheers Quay, by permission of the River Wear Commissioners and Bartram and Sons, Ltd., before representatives of port authorities, harbour boards and shipping companies. An unusually difficult site, for crane operation, was chosen deliberately for the trials in order to demonstrate the capabilities of the crane when engaged in working a ship's hold under



MOBILE CARGO CRANE

circumstances more difficult than those obtaining in the United Kingdom, but likely to be encountered overseas. In our photograph reproduced herewith, the crane can be seen on test.

The crane builders consider that the latest product is complementary to existing quay cranes, and its usefulness lies in the fact that it combines the mobility, flexibility and manœuvrability of the pneumatic-tyred mobile crane with the long outreach, considerable height and excellent visibility of the operator, which are essential for working the holds of ocean-going ships. The installation of new, or the replacement of obsolete, permanent cargo handling plant involves high capital cost, which is not always justified by the volume of cargo at a particular quay, so that on economic grounds the new crane should prove of value in that its handling capacity can be concentrated or dispersed as required by the demands throughout the port area.

The crane is electrically operated, but is independent of trailing cables and power points, since it carries its own generator, which is driven by either a diesel or a petrol engine. An individual electric motor is provided for each of the four motions, hoist, derrick, slew and travel, and the builders' variable-voltage system provides a simple control of all operations, more than one of which can be carried out simultaneously. Six large pneumatic-tyred road wheels spread the load over a large area so that the wharf apron and roadways cannot be damaged, and when in position for handling loads a fixed base is established by the extension of telescopic girder stabilisers.

Specification particulars of the crane state that it will lift 3 tons at 30ft radius to a height of 63ft above quay level from a point 50ft below quay level, or 2 tons can be handled at 40ft radius to a height of 55ft above quay level from 58ft below, or 1½ tons at 50ft radius to 40ft above quay from 73ft below. These duties, which appear to be adequate for serving the holds of medium size ocean-going vessels and for handling general cargo are associated with a hook speed of 150ft per minute when lifting 1½ tons and free barrels will be available for gravity lowering.

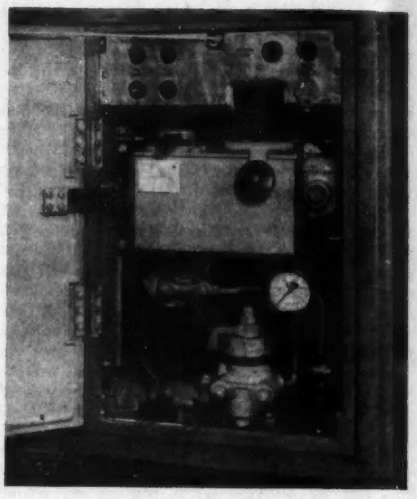
When operating the crane the driver in his cabin is seated at 36ft above quay level, which is sufficient to give him a clear view of the deck and the far side of the hatch. Full circle slewing is possible in either direction without limit and the 50ft jib, of tubular construction, can be derricked from maximum to minimum radius in ten seconds. The controls incorporate many automatic safety devices, including limit switches to prevent derricking the jib beyond the prescribed limits, hoist and lowering switches, safe load indicator, electromagnetic brakes and reversing steering, which enables normal steering to be effected by the driver, whether the jib is towards the front or rear of the chassis during travel. Power-assisted road wheel brakes are fitted and the equipment includes electric lighting and starting. The crane can move under its own power from point to point with the tower erected, but to enable the unit to pass under obstructions a special arrangement allows the tower to be lowered to give a clearance height of 17ft 9in. For the lowering and erection of the tower the crane is completely independent of any assistance from other plant. The speed of travel, it is understood, is up to 4 m.p.h.

Another item of equipment, manufactured by the company, included in the trials was a Mark S.810 self-propelled diesel/electric or petrol/electric mobile crane, capable of lifting 6 tons and suitable for moving heavy loads from wharf apron to transit sheds, and for loading on to road and rail transport. Two "Electric Eel" industrial tractors demonstrated how to avoid congestion by maintaining a constant flow of goods from the wharf to the transit sheds. The smaller tractor has a drawbar pull of 1200 lb and the larger a pull of 4000 lb, and both machines are powered by electric batteries so that there is no danger of fire or of contamination of cargo. Another item of cargo handling plant seen was the "Electric Eel" load carrier which has a platform measuring 8ft by 3ft 6in, and an offset control column to permit the transport of long loads.

After the demonstration the representatives attending the trials were asked for comments and suggestions relating to the performance of the crane, and when the constructive criticisms received have been acted upon the new crane will go into production.

Tube Cars with Shunting Control Equipment

A NEW design of tube car is being introduced on London Transport's Northern and Bakerloo lines to operate with the 1938 tube stock. For shunting purposes it is fitted with a simplified form of driver's control equipment designed to provide the maximum passenger accommodation. Hitherto it has been the practice for this stock to be made up into three and four-car units having a driving cab at each end so that a seven-car train can be divided into two separate units. In most cases, when trains are reduced in length after the peak service, only one unit remains in service, the other



SHUNTING CONTROL CABINET WITH DOOR OPEN

returning to a depot or siding near the uncoupling point. To provide a normally equipped driving cab for this purpose is not only expensive but also results in a loss of valuable passenger accommodation. A further important consideration is the increased distance between passenger doors when two driving cabs are adjacent, causing local crowding on the platform in peak service and a consequent increase in the station-stop time. By eliminating one of the cabs, at the point where the only driving facility required is that of enabling a unit to be shunted to or from depot, and by substituting a passenger door, the rapid loading of passengers is greatly facilitated.

Accordingly, the driving equipment in the new cars has been reduced to a minimum and has been housed in a cabinet let into the end panel of the car similar to the normal arrangement of the guard's door control equipment. The equipment provided is adequate for all normal shunting movements, and, in addition to the control cabinet, includes an automatic coupler and a tripcock. The latter is considered essential as some of the shunting movements take place on service tracks where automatic signalling with train stops is in use. Electric marker and tail lights are fitted on the headstock and a bracket is provided for an oil lamp in emergency.

The main items of equipment in the shunting control cabinet can be seen in the photograph reproduced herewith. In the upper part of the cabinet there are push buttons for the control of tail and marker lights, overload relay reset and control governor cut-out. Below this push-button assembly, there is a master controller unit incorporating a selector switch (operated by the driver's master controller reverser key) and a large push-button switch for operation by the palm of the hand.

The selector switch has two positions giving "shunt" and "series," whilst the push button takes the place of the operating handle in a normal master controller. To the right of the master control unit is an interlock switch, connected in the passenger door interlock circuit, which is "made" when the cabinet door is closed, thus ensuring that the cabinet must be properly closed when not in use. The cabinet door lock is key operated. Mounted on the base of the cabinet is the brake equipment, consisting of a No. 6 driver's brake valve fitted with pressure-limiting check valve

CONTROL CABINET CLOSED

and train line pressure gauge, a key-operated isolating cock for the brake valve and a hand-operated isolating cock for the tripcock. The two isolating cocks, shown in the first photograph in the closed position, are mechanically interlocked with the cabinet door so that both must be in this position before the cabinet door can be closed. Between the master control unit and the brake equipment are the whistle valve and isolating cock controlling a standard pneumatic whistle fitted on the outside end panel of the car.

Our second illustration shows the shunting control cabinet with its door closed. When using this driving position the motorman observes the track through the central corridor door and operates the master controller or the brake valve as required with his left hand.

Seventy new cars of this kind are being manufactured, and a further twenty-two are being provided by converting non-driving motor-cars of 1938 tube stock.

A Foundry Modernisation Scheme

In our notes on Dowlais in the Seven-Day Journal on page 37, we mention that a programme of modernisation and extension is being carried out at the ironfoundry of the Guest Keen Baldwins Iron and Steel Company, Ltd. This foundry has been engaged for many years in the production of high-grade castings such as ingot moulds, slag ladles, &c., for the parent company and a number of associated steel works and other firms. With the completion of the modernisation scheme, which is now in an advanced stage, and is costing a quarter of a million pounds, a larger capacity will be available for the supply of iron and non-ferrous castings for the general market. The reorganised foundry is designed to produce weekly some 500 tons of castings weighing up

MAIN FOUNDRY FLOOR

to 20 tons each, as well as about 5000 lb a week of non-ferrous castings. It has a particular advantage in that facilities are available in adjacent machine shops to rough or finish machine the castings if required. A drawing-office and a large pattern shop which serve the foundry make it possible for all stages in the production and finishing of a casting to be completed within the one establishment. The decision to reorganise and modernise the foundry was influenced by the fact that not only was it situated in a position where good means of transport were available to a wide potential market for the increased production which would be made possible, but that it had a large staff of highly skilled workmen capable of undertaking a wide variety of special work of an individual character.

The foundry covers an area of some 38,250 square feet and on this page we reproduce a photograph showing part of the main floor now in process of rearrangement. Four cupolas with a capacity of 10–12 tons per hour serve the foundry and are situated midway along one side of the building. Raw materials are supplied directly to the cupola charging platform from trucks on a rail siding arranged at platform floor level. An overhead crane serving this platform discharges the material from the trucks either into stock bins or directly into cupola charging boxes on a weighing table according to the run of the work. Scrap for charging purposes is stored and broken down in a large stock yard in front of the foundry. A crane serving this yard loads the scrap into rail trucks for transfer to the charging platform as required.

Under the modernisation scheme a new cupola with a capacity of 5 tons per hour has been installed on the opposite side of the building to supplement the output of the main melting unit. This cupola has an automatic skip charger which can be fed from rail trucks or small storage bins at the foot of the unit.

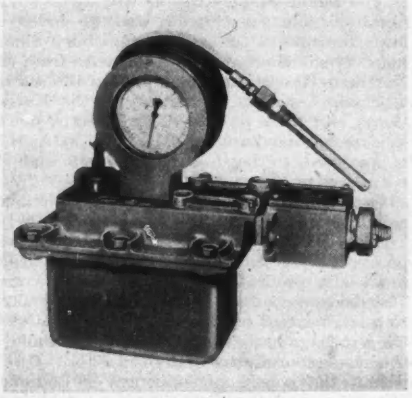
The main foundry floor is well served by overhead cranes with a capacity of up to 40 tons and is generally divided into areas for heavy and light floor moulding and pits where the large ingot moulds, ladles, &c., are made. Three sand slingers are arranged at suitable points along the centre of the foundry, and in one corner a new "August" sand preparation unit with a capacity of 8–10 tons per hour has been installed. Knock-out stations are set at various points in the floor and the sand from them drops on to an underground conveyor system for transfer to the preparation plant. An overhead conveyor delivers prepared sand along the length of the foundry, and this sand is ploughed off into storage bunkers at various points. Along the same wall of the building as the cupolas are seven drying stoves of adequate size to take the largest moulds likely to be required in the foundry. Although the knocking out of moulds and fettling can be seen in progress in various parts of the main floor in the photograph, it is planned to move all this work to one section in the near future. The sand slinger to be seen in the centre of the shop is a new machine with a large effective working radius.

The brass foundry has an area of 12,600 square feet and is laid out for the production of high-quality brass, phosphor bronze and other castings, in addition to non-ferrous scrap melting to produce pig. Its three oil-fired melting furnaces of 200 lb to 600 lb capacity give an output of some 5000 lb of castings per week.

A Flameproof Thermostat

To meet the requirement for safety in mines a special version of flameproof thermostat has been developed by the Electrical Apparatus Company, Ltd., St. Albans. It is designed for the protection of motor-driven air compressors and is Buxton certified for groups I, II and III.

The equipment comprises a wall or bracket-mounted flameproof enclosure which houses the thermostat switch itself. The switch is connected in the starter or circuit breaker "stop" control circuit and is operated by a sensitive



FLAMEPROOF THERMOSTAT

phial, through a length of armoured capillary tubing. Since any substantial rise in temperature on the compressor is conveyed to the air outlet, the sensitive phial is inserted in the supply line as close as possible to the discharge point. A clear indication of the actual discharge air temperature is given by a pedestal dial thermometer which is mounted on the main thermostat enclosure.

A convenient method of varying the tripping value is provided, though, to prevent unauthorised adjustment, it is necessary to remove the main cover after isolating the supply.

The thermostat itself embodies an airbreak, butt-contact, normally closed switch, magnetically assisted to give a snap action, and arranged to open on reaching the predetermined temperature. Several standard ranges are available. The standard length of armoured capillary tubing is 10ft and the weight of the complete equipment is approximately 50 lb. The only external wiring which it is necessary to arrange is the twin cable connection between the switch and the control gear associated with the compressor motor.

South African Engineering News

(By our South African Correspondent)

Plant for Uranium Concentration

Valuable equipment to be used for the preparation of uranium concentrates from the mine dumps on the Witwatersrand is at present being manufactured in Port Elizabeth. Pumps worth many thousands of pounds are being built in the International Combustion Africa Ltd.'s plant in Neave Township, and, after being rubber lined by the Goodyear Tyre and Rubber Company, Uitenhage, shipped to Johannesburg.

The first pumps to come off the line were dispatched recently and will soon be in operation on the new uranium projects on the Reef. For the past six months the foundry and machine shops of I.C.A., Ltd., have been working at full pressure to produce this valuable equipment. With the arrival of more skilled artisans, production is expected to be increased.

Southern Rhodesia's Four-Year Railway Plan

Southern Rhodesia's second four-year plan of capital development, which has recently been tabled in Parliament, covers a total outlay of £92,476,000 in the period 1951–55, and more than £30,000,000 of this is allocated to the Rhodesia Railways.

Both the major railway links to be constructed in the next few years, at a total cost of at least £10,250,000, are expected to operate at a loss. The first, known as the South-East connection, will cover the 160 miles from Bannockburn to the Mozambique border, a link which will provide direct access to the port of Lourenço Marquez. Construction has just been commenced and is expected to be completed in about three years. The second, known as the Sinoia–Kafue cut-off, will involve 115 miles of new construction and 95 miles of improvements to the existing Salisbury–Sinoia line. It will shorten the rail distance from the Northern Rhodesian copper belt to the sea by 527 miles, and provide access to the Kariba Gorge, site of the proposed hydro-electric power scheme on the Zambesi River. Construction is expected to begin early in 1955 and be completed in 1960.

The conclusions reached by the planning committee regarding these two schemes are :

South-East Connection.—From the railway point of view this line is not likely to be financially profitable for some time to come. The development of the territory is dependent to a large extent on the provision of a railway. On a mileage basis it would place the whole of the present railway system west of Gwelo within the sphere of influence of Lourenço Marquez, until the Sinoia–Kafue cut-off is in operation, and it would provide an alternative route to the sea and access to a better port.

Sinoia–Kafue Cut-Off.—From the railway point of view, this line is likely to be a financial responsibility for some years, but there are strategic and commercial advantages which cannot be assessed. The development of the territory traversed is largely dependent on the construction of a railway line.

A strip of land 500 yards wide and more than 80 miles long, extending from Lion's Den siding, north of Sinoia, to the Zambesi River, north of the Kariba Gorge, has been reserved against prospecting and pegging, the route being that expected to be taken by the Sinoia–Kafue rail link.

A rough estimate of the total number of miles of track that would have to be laid to the Zambesi is 115.

Asbestos Production

It is stated that a gradual change from gold to asbestos production will be considered by the Antelope Mine of Southern Rhodesia when the results of further investigations of serpentine deposits on its property will have become available in a few months' time.

Gold mining operations have exposed chrysotile asbestos in the serpentine bodies in various positions in the mine over a period of years, and there were surface exposures on other claims on the extensive property. On the Yadkin section, cross fibres were present in workings closed down some years ago and were now being tested by development. At the mine itself, slip fibres had been exposed, but not developed, between the twelfth and fourteenth levels at depths down to 2000ft. Prospecting of the surface exposures was in progress. Samples tested showed that the asbestos fibre, especially the slip fibre, was of good quality, but it was too early to assess the economic importance of the deposits.

The possibility of such a development is interesting because of the advantages which would accrue from starting asbestos mining with an existing organisation and development at depth. Like most Southern Rhodesian gold mines, the Antelope Mine, a medium-sized producer with a monthly output of about 600 oz to 650 oz of gold, staffed by about twenty-three Europeans and 450 natives, has been struggling against rising costs. A switch to the production of asbestos would, therefore, open interesting prospects for this enterprise.

It may be mentioned, also, that in the Belingwe area, the Aqua gold mine was recently acquired by interests associated with the adjacent serpentine asbestos blocks, in order to explore from the deeper levels of the gold mine the depth prospects of the asbestos claims.

Railway Line to Serve Iscor

The construction of a new railway line in the North-Western Cape to carry the Postmasburg–Lohathla line to Sishen, a distance of 19 miles, at a total estimated cost of £490,000, is being considered by Parliament. It is proposed to use 81 lb rails on 2112 new steel sleepers per mile, which means that the line will be of main line standard. The line will be used principally for the conveyance of iron ore for the South African Iron and Steel Industrial Corporation, Ltd. (Iscor), which has undertaken to indemnify the Administration against all losses in working for a period of thirty years. The construction of the line is expected to take about twelve months, and work will be commenced as soon as Parliament has approved of the proposal. The Railway Board investigated the project last year and recommended the building of the line.

Copper Prospecting Near Sinoia

Prospecting operations 35 miles north of Sinoia have revealed deposits of copper ore in Southern Rhodesia's Lomagundi district. It is understood that the official forecasts of railway traffic for 1956 will include a tentative figure for copper concentrates to be carried to Beira from Sinoia, and that the route to be followed by the Sinoia–Kafue "cut-off" may be influenced by the results of the development work now in progress on the copper ore body.

French Engineering News

(By our French Correspondent)

Electricité de France has published a further account of its recent activities. Thermal power equal to 228MW was installed in 1951, against only 12MW in 1947; 39MW in 1948, 197MW in 1949, and 240MW in 1950. Hydro-electric power production has made amazing strides. By the end of 1951, 1506kWh had been added to the annual production, against only 718kWh in 1947.

In 1951 the dam at Bort on the Dordogne was completed but the scheme will not come into production until the winter of 1952. In 1951 some 1,137,400 cubic metres of concrete were placed in the construction of dams and other hydro-electric works. In 1947 this figure was 526,000 cubic metres, and in 1950 it was 1,456,000 cubic metres.

In 1951 six thermal plants came into production: Dieppedalle, 50MW; Comines, 50MW; Lourches, 40MW; Caen, 30MW and Brest, 40MW.

Hydro-electric progress was even more important. The extra 1506kWh came from thirteen new turbo-alternator sets installed in new or existing power stations. The most important scheme completed in 1951 included the Chastang dam, an arched structure 85m high and 350m long. The power station associated with this dam has been designed to take three turbo-alternator sets but only two have been installed so far. They will produce about 550 million kWh per year. The turbines are vertical axis machines of 115,000 h.p. and the alternators are each of 90MVA, 150 r.p.m., generating at 15kV.

* * *

The Centre d'Etudes et de Recherches des Charbonnages is to be enlarged. It was opened last October, having been set up to study every aspect of coal mining and the use of coal, and has proved a far greater success than was believed possible. Situated at Verneuil, its laboratories employ 300 specialists; mining methods, the use of explosives, ventilation, hygiene and lighting in the mines are amongst the subjects studied. Much time is given to experiments with coal washing. Some forty-seven different kinds of coal from all over France have passed through the laboratory for washing experiments and new washing apparatus is being tried out. The agglomeration and use of coal dust takes an important place in the laboratory work. The agglomeration of sludge and tailings by means of a bitumen emulsion is now being investigated. Efforts to agglomerate dust without the use of binder are also being made.

* * *

The dam at Vimont has now been officially inaugurated. This dam is situated in the Massif de la Sainte-Victoire. It is 87m high and 260m long. It will form an artificial lake some 500 acres in area and holding 4 million cubic metres of water. The lake will make irrigation possible for an area of over 15,000 acres, which will include no fewer than sixty communes. The construction of this dam is part of a project which will include the widening of an arm of the Verdon Canal over 73km and the cutting of a large number of irrigation canals in the Roquevaire, Aubagne and La Ciotat regions.

* * *

Recent decisions taken by the French Government are being interpreted as an indication of further important modernisation of French mines. The target for 1952 has been fixed at 60 million tons, against 55 million in 1951, and further modernisation has been ordered for mines in the Nord and Pas-de-Calais areas. It includes new washing plant similar to that installed in the eastern areas. Cages for lowering and bringing trucks to the surface will be replaced by skips holding 9 cubic metres and capable of handling 5000 tons of coal daily. It is interesting to note that most of the new material now being installed in French mines is of French manufacture. Some of it is entirely French; some is built in France under foreign licence.

Industrial and Labour Notes

The Expansion of World Trade

Opening an adjournment debate in the House of Commons on Tuesday of last week, on the subject of expanding world trade, Mr. Robson Brown, A.M.I.Mech.E., suggested that at present there were unhappy signs that the international unity of the free nations in the economic field was not as strong and effective as it should be. He said that unless effective action was taken in regard to the completion, reduction or slowing down of rearmament the world might well drift from what was at present a trade recession to another world slump.

Capital, Mr. Robson Brown continued, must be put to the best use, labour must be given every opportunity, and material must be produced at keen economic costs. That collective responsibility on the part of each industry, managements and unions in each industry would, he thought, be of powerful value to the Ministers of State and their advisers, who had to keep in view the complete moving picture of industrial progress, particularly in so far as overseas trade was concerned. In future, Mr. Robson Brown asserted, industry must retain a greater share of its current earnings for re-equipment, or soon it would earn nothing at all. Further, people could not be expected to go on striving unless personal taxation was reduced. The workers wanted to be confident that the Government would not tolerate avoidable unemployment, and he suggested that a panel of experts should be set up to make rapid and positive recommendations about future employment trends.

In a reference later in his speech to overseas development, Mr. Robson Brown said that with the deep sense of stewardship towards the undeveloped countries, there came a magnificent opportunity for British industry not only to export equipment to new markets, but also to provide skilled instructors to supervise its installation and use. The people should be allowed to follow the plant, and the expansion of facilities for technological training should be speeded up. During that "galloping period in world history," Mr. Robson Brown observed, Britain should set herself no less an ambition than to become the premier technological training and recruiting ground for the free world. With the new opportunities for training and an abundant scope overseas for the trained men, the British artisan of to-day had every prospect of becoming the skilled technician of to-morrow.

Index of Industrial Production

The index number of industrial production (1946=100), which is prepared by the central statistical office of the Treasury, has been provisionally estimated at 139 for all industries in April this year, compared with a revised figure of 149 for March. In the corresponding months of 1951 the figures were 151 for April and 141 for March. It should be noted, however, in making comparisons, that the index was affected by the Easter holiday in March last year and in April this year. Taking the manufacturing industries only, the index number for April this year has been estimated as 143, compared with 154 in March, and 158 and 147 in April and March respectively last year. The Treasury says that, on the basis of information so far available, the index for all industries for May this year is expected to be 148 or 149.

Copper Price Increase

On Saturday last the Ministry of Materials announced a further increase in the price of copper. From that day, July 5th, the price of electrolytic copper has been advanced from £281 to £287 a ton, delivered consumers' works. Discounts and premiums remain unchanged. Corresponding adjustments are to be made by the Ministry of Supply in the controlled prices of scrap and secondary metal. The Ministry of Materials has stated that this price increase follows the conclusion of further negotiations with Commonwealth suppliers. A meeting has now been arranged between the Ministry and the suppliers to discuss future pricing.

The British Non-Ferrous Metals Federation

The annual general meeting of the British Non-Ferrous Metals Federation was held in Birmingham on Thursday of last week, July 3rd, when Mr. H. E. Jackson, of the Metals Division of Imperial Chemical Industries, Ltd., was elected president. Mr. W. F. Brazener and Mr. H. C. Gibbins were elected vice-presidents.

Following the Federation's custom, the annual report was presented by the outgoing president, Mr. W. J. Terry. In the course of it Mr. Terry referred to the price of copper, saying that the continued rise since the end of the second world war—when the price was £62 a ton—was a cause for alarm. It was only natural that when high prices were ruling, customers were inclined to hold off and restrict their orders for immediate and essential requirements. Because of those high prices and world events since 1939, Mr. Terry continued, there had not been any encouragement to develop new uses for non-ferrous metals, and for that reason research and development had not been able to play the important part in the non-ferrous metals industry which they might have done. The development of new products and new outlets for existing products was essential to progress, which had been retarded by high prices, Government controls and world events. Mr. Terry made it plain that he did not suggest that no new research or development had taken place, but he believed that they had not played so important a part as they might have done in normal times. Continuing his observations about the prices of non-ferrous metals, Mr. Terry said that recent events in the U.S.A. and Chile had served to confirm the desirability for the reopening of the London Metal Exchange. It was understood that the principal obstacles preventing that being done were the questions of foreign currency and ample supplies. It was earnestly to be hoped that ways would be found to overcome those difficulties in the near future.

On the subject of the exports of the non-ferrous metals industry, Mr. Terry pointed out that they were still subject to Government licensing, which restricted the volume to 80 per cent of that exported in 1950. That control, he claimed, did not operate fairly as between federated firms and was not sufficiently flexible. Negotiations were therefore at present in progress with the Board of Trade with a view to some relaxation in the export licensing system. It was hoped that the negotiations would result in those companies which were suffering from a falling off in demand at home being permitted some measure of relief in their export arrangements. When virgin metals became more plentiful, Mr. Terry suggested, firms would again be in a position to supply their traditional markets and customers with their total requirements.

Human Relations in Industry

The twenty-ninth annual conference on "Human Relations in Industry," arranged by the Industrial Welfare Society, was held at Keble College, Oxford, from June 28th to July 2nd, and the Society has this week issued a résumé of the papers presented at it. They deal with several matters including joint consultation through State legislation, as practised in France; joint consultation in Sweden through trade union-management agreement; the training of supervisors in Sweden; physical working conditions; and human problems in large-scale organisations.

One of the papers was entitled "Attitudes Towards Productivity in the U.S.A.," and was presented by Mr. William B. Barton, of the Labor Relations Department of the U.S. Chamber of Commerce, Washington. In it, reference was made to incentives, Mr. Barton saying that, generally speaking, employers in the U.S.A. believed in bonus or production incentive schemes, though they had found that the decision on the kind of scheme to employ was anything but simple. The incentive system that worked best appeared to be that which established a certain amount of friendly competition among employees. On the subject of competition, Mr. Barton said that employers in the U.S.A. believed that it was one of the best stimulants to research and technological development, as under a system of competition each firm wanted to outdo the other in developing better methods. It was true that the unions and employees sometimes opposed new methods of production, but it had been found that such difficulty frequently arose from the failure of the employees to understand what was being done.

Trade Disputes

The number of stoppages of work through industrial disputes, reported to the Ministry of Labour as beginning in May, was 175. In addition there were nineteen stoppages of work, which began before May, in progress in the early part of that month. In those 194 stoppages, 40,900 workers were involved directly and indirectly during May, with the result that, in the aggregate, 178,000 working days were lost in the month. In April 164 stoppages of work through disputes involved 36,500 workers and caused a loss of about 80,000 working days. By far the greater portion of the stoppages in May occurred in the coal mining industry. In them 21,200 workers were concerned, the aggregate number of working days lost being 75,000. In the first five months of this year 740 stoppages of work through disputes were reported in the United Kingdom. The number of workers involved in them was 156,700 and the aggregate number of working days lost was about 702,000. In the comparable period of 1951 there were 738 stoppages, involving 182,700 workers, and causing a loss of 917,000 working days.

The Imperial Smelting Corporation

In the course of his speech at the annual general meeting of the Consolidated Zinc Corporation, Ltd., which was held in London recently, the chairman, Mr. John R. Govett, reported on the Corporation's activities in various parts of the world. Dealing with the affairs of the Imperial Smelting Corporation, Ltd., in the United Kingdom, he said that last year the level of output of that company's products did not in some cases reach the high figures of 1950 because transport difficulties in Australia affected supplies of zinc concentrates from the Broken Hill mines. The horizontal distillation processes at Avonmouth and Swansea were modified to obtain maximum recovery in order to make the most economic use of the smaller tonnages of raw material available and that involved a lower total production of zinc metal by those units. But towards the end of last year the Australian transport situation improved and the prospects for future supplies of zinc concentrates became more satisfactory.

The bulk of the Imperial Smelting Corporation's sulphuric acid production, Mr. Govett continued, was normally derived from the roasting of zinc ores so that the smaller consumption of concentrates had to be offset by using alternative raw materials. As a result, sulphuric acid output fell a little short of the record figure achieved in 1950. The production of zinc alloys was affected by reduced Government allocations of zinc for their manufacture, but zinc dust and cadmium outputs last year established new records through the higher metallurgical efficiency of improved equipment.

Notes and Memoranda

Rail and Road

DOME OF DISCOVERY ESCALATOR FOR ALPERTON STATION.—London Transport has purchased from the demolition contractors the escalator which was used in the Dome of Discovery at the Festival of Britain. It is to be installed as soon as possible at Alperton Station, Piccadilly Line, where passengers have to walk up from the ticket hall to the platform. The escalator was built by J. and E. Hall, Ltd.

Air and Water

M.V. "EBRO."—The "Ebro's" machinery space is ventilated by four 30in diameter "Torpedo" supply fans, provided by Thermotank, Ltd., each driven by a 4 h.p. motor and delivering 12,500 cubic feet per minute at 1½in. water gauge, giving a total of 50,000 cubic feet per minute, a quantity which was attributed erroneously to each fan in our article of last week.

ROYAL AERONAUTICAL SOCIETY.—The council of the Royal Aeronautical Society has announced that Her Majesty The Queen has graciously honoured the Society by becoming its Patron. At a recent council meeting the following were elected vice-presidents of the Society :—Mr. G. R. Edwards, F.R.Ae.S., Sir William Farren, F.R.S., F.R.Ae.S., and Mr. P. G. Masefield, F.R.Ae.S.

HANNINGFIELD WATER SCHEME.—The construction of the Hanningfield reservoir, which constitutes the major work in the Hanningfield water scheme, commenced on July 1, 1952, the successful contractor being W. and C. French, Ltd. Preliminary work on roads and site investigations, &c., has been in progress for some time; the laying of the 48in raw water main from Langford to Hanningfield, a distance of some 9 miles, also commenced last month. The joint promoters of the scheme are the Southend Waterworks Company and the South Essex Waterworks Company, who will share the additional water resources made available, and also, under certain conditions, afford bulk supplies to other authorities.

Miscellanea

ENGINEERING BRICKS.—The British Engineering Brick Association, Temple Courts, Temple Row, Birmingham 2, has published a leaflet describing the properties and uses of the two classes of clay engineering bricks given in B.S.S. 1301. The member firms of the Association which manufacture such bricks are listed in the leaflet.

GEOLOGICAL CONFERENCE.—An International Geological Congress will be held at Algiers from September 8th to 15th, and the subjects to be discussed include submarine topography, geology of the Mediterranean and Middle Eastern areas, and the hydrology of arid regions. During the congress many of the scientists attending will study the geological conditions in the Algerian Sahara and the Atlas Mountains.

COPPER AND ITS ALLOYS.—We have received from the Copper Development Association, Grand Buildings, Trafalgar Square, London, W.C.2, a copy of its publication No. 36, "Classification of Copper and Copper Alloys." The last edition was published in 1948 and in the new edition the tables have been revised to incorporate new British Standards and matter on additional copper-base alloys has been included.

COMPRESSOR DEVELOPMENTS.—James Howden and Co., Ltd., has issued a booklet entitled "Recent Developments in the Lysholm Compressor," by W. Bailey, B.Sc. The effect of recent developments are listed and there is a note upon the volumetric and adiabatic efficiencies. This is followed by a review of the characteristics of the compressor, with special reference to inlet, leakage, built-in compression, outlet and windage losses. The development work to reduce losses and increase adiabatic efficiency is stated and paragraphs touch upon the new lobe shape, length/diameter ratio, wrap angle and mechanical design. A series of diagrams illustrate the points discussed.

TIN RATE PUBLICATION.—More than half the usage of tin is in coatings for the protection of steel and other metals from rusting and corrosion, and the Tin Research Institute, of Greenford, Middlesex, has published a book entitled "Corrosion Resistance of Tin and Tin Alloys," by Mr. S. C. Britton, M.A., who is responsible for the research work on corrosion at the Institute. After a section on atmospheric corrosion there are sections on corrosion by acids and by alkalis in both of which the influence of atmospheric oxygen is often decisive. Milk products are separately discussed. The tin alloys dealt with principally are solders, bearing metals and bronzes. There is a brief account of the various methods by which the coatings can be produced. Experiences with canned foods figure largely in the discussion of tinned steel containers for acid products and the effects of oxygen and of inhibitors are reviewed. The book concludes with a review of the properties of tin-lead, tin-zinc, tin-cadmium, tin-copper (speculum especially) and the new tin-nickel electroplate which has unusual qualities of corrosion and tarnish resistance.

MR. H. CECIL BOOTH'S RETIREMENT.—This week the British Vacuum Cleaner and Engineering Company, Ltd., Leatherhead, has announced the retirement from the board of Mr. H. Cecil Booth, who has been chairman of the company for forty years, and was also for many years managing director. This retirement is at Mr. Booth's own request, in view of his advancing age. He is now in his eighty-first year. It will be recalled that a year ago the company celebrated the fiftieth anniversary of Mr. Booth's invention of the vacuum cleaner. Mr. J. J. Hambridge, who has been a director of the company for thirty years, has been appointed to succeed Mr. Booth as chairman. In addition, he will continue to act as senior managing director, which office he has held for several years.

GAS TURBINE FOR OPERATION ON METHANE.—For installation at the Mogden works of their West Middlesex main drainage undertaking, the Middlesex County Council has accepted a tender of Harland and Wolff, Ltd., for a gas turbine compressor plant of approximately 1000 h.p. to be supplied at an inclusive cost of £39,900. The turbine will be designed to operate on methane gas obtained from the digestion of sludge, and also on dual fuel (oil and methane). The machine will be of the two-shaft, open-cycle type, delivering 25,000 cubic feet of free air per minute at a pressure of 7½ lb per square inch for the operation of the aeration tanks of the activated sludge plant. The turbine will be installed in the existing power station, where ten Harland and Wolff engines, each of 650 h.p., have already completed an average of 100,000 hours' running in the sixteen years of their operation.

ENGINEERING RESEARCH FELLOWSHIPS.—The British Thomson-Houston Company, Ltd., has recently instituted the award, annually, of engineering research fellowships. The award is open to honours graduates who are in their last year of apprenticeship with the company. The holder of a fellowship will engage in engineering research for a limited period—of one to three years—either wholly within the company or partly within the company and partly at a university. He will work under the supervision of a senior engineer of the company and under the guidance of a research fellowship panel set up for the purpose. The company's director of research and education is chairman of the panel, which includes other senior B.T.H. executives, and, in addition, Professor E. B. Moullin and Professor Willis Jackson. This year fellowships have been awarded to P. H. G. Allen and P. C. McNeill.

METALLURGICAL CONFERENCE.—The Leeds Metallurgical Society proposes to hold a Metallurgical Conference, which is being undertaken especially for the younger metallurgist and engineer and for that reason has been arranged for the week end September 5th to 7th. It is hoped to hold the Conference at a venue near to Leeds and the basic subject for discussion will be "Problems Arising from Metal Scarcities and the Use of Alternative Materials." The project has the support of the Metal Economy Committee, Ministry of Supply, and speakers of national standing will initiate and take part in the discussions. Other subjects suggested for discussion include: heat treatment of alternative En steels; alternative protective coatings, substitution of non-metallic materials and scrap recovery. The inclusive fee for the conference will be about £1 15s., plus a registration fee and enquiries should be addressed to Dr. K. J. Irvine, Department of Metallurgy, The University, Leeds, 2.

INTERNATIONAL SYMPOSIUM ON COMBUSTION.—Some particulars have been announced of an International Symposium on Combustion, which is to be held at the Massachusetts Institute of Technology from September 1st to 5th. The symposium will be open to all who are interested in combustion. Since the last symposium was held in 1948, the quickening pace of combustion research throughout the world has yielded an important body of new knowledge. Much of this knowledge will be presented at the symposium in about 100 papers from Great Britain, France, Holland, Belgium Germany and Japan, as well as from the research laboratories and educational institutions of the U.S.A. The papers are now being reviewed by a sub-committee, emphasis being placed on the physical aspects of combustion, particularly wave phenomena and turbulence, treated from both experimental and theoretical standpoints. Requests for registration forms or for further information on the symposium should be addressed to the Combustion Symposium Committee, Massachusetts Institute of Technology, Cambridge, 39, Massachusetts.

ALUMINIUM DEVELOPMENT.—The Aluminium Development Association, 33, Grosvenor Street, London, W.1, has issued an abridgement of its annual report, 1951. Progress has continued in many fields of application, but shortage of aluminium created difficulties for short-term items. The report states that the Council has authorised the preparation of a programme of work on a three-year basis, and it contains short accounts of the activities of the various sections of the Association. The publications and technical memoranda are listed and an analysis of the inquiries received during the year. Educational work continues to expand and the report comments on the number of lectures delivered, films shown and the circulation of wall charts. Sections of the report deal with the work of the various technical committees, including research, marine, transport, structures, and building developments, followed by brief notes upon the activities of the castings, mining equipment, oil industry, electrical engineering, and standards committees. The report concludes with a short statement concerning the Association's contact with other organisations.

Personal and Business

MR. N. D. MILES has been appointed general supply manager of Remington Rand, Ltd.

ACHESON COLLOIDS, Ltd., has opened a West of England office at 103, Promenade, Cheltenham (telephone, Cheltenham 3847).

THE WESTERN REGION OF BRITISH RAILWAYS announces the appointment of Mr. J. R. Hammond, A.M.I.C.E., as district engineer, Cardiff.

ELDER DEMPSTER LINES, Ltd., announces that Mr. A. E. Muirhead and Mr. A. M. Bennett have been appointed directors of the company.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., Rugby, states that Mr. P. E. Warden, manager of drawing-offices, has completed fifty years in its service.

J. M. J. MAUS, Ltd., 35, New Broad Street, London, E.C.2 (telephone, London Wall 6934), has been appointed agent for Harburger Eisen and Bronzewerke, A.G., Hamburg-Harburg.

FERRANTI, LTD., Hollinwood, Lancs, states that Mr. R. M. Hobill has been appointed transformer sales manager in place of Mr. G. B. Proctor, who has resigned. Mr. H. G. Binns has been appointed transformer contracts manager.

THE HAWKER SIDDELEY GROUP announces that Air Marshal Sir Hugh S. P. Walmsley, Commander-in-Chief, Flying Training Command, is to succeed Group Captain R. J. F. Barton as managing director of Air Service Training, Hamble.

MR. S. SMILEY, Mr. J. Orwig Jones, A.M.I.Mech.E., and Mr. Roy N. Fletcher, have been elected directors of Edward G. Herbert, Ltd., Levenshulme, Manchester. Mr. Alan Kiernan, M.I.Mech.E., has been appointed managing director, and Mr. Tom Hitchens, works manager.

THE DE HAVILLAND AIRCRAFT COMPANY, Ltd., Hatfield, announces the appointment to its board of directors of Mr. R. M. Clarkson, A.C.G.I., F.R.Ae.S., assistant chief engineer and head of the aerodynamics department, and Mr. A. Stewart Kennedy, secretary of the company.

Launches and Trial Trips

LONDON MAJESTY, oil tanker; built by the Furness Shipbuilding Company, Ltd., for London and Overseas Freighters, Ltd.; length between perpendiculars 525ft, breadth moulded 71ft, depth moulded 39ft 3in, deadweight 18,070 tons, summer draught 30ft 5½in; twenty-seven cargo oil tanks, two pump rooms, four 400 tons per hour duplex steam cargo pumps and one stripping pump; steam deck machinery, two 60kW steam generators, one 25kW diesel generator; N.E.M.-Doxford single-acting, two-stroke oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m., two Scotch boilers. Trial, June 25th.

British Patent Specifications

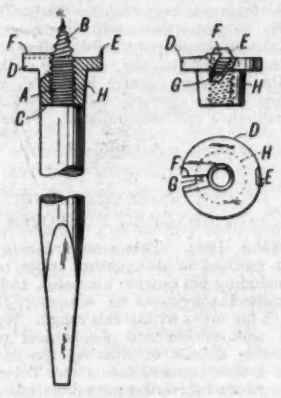
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

WORKSHOP TOOLS AND APPLIANCES

674,018. November 30, 1949, WOOD BORING BITS, Arthur Ernest Taylor, Heather Lea Place, Ware, Sheffield.

This invention relates to wood boring bits and its object is to provide an improved boring bit with interchangeable cutter heads for boring different sizes of holes. The tool comprises a driving spindle provided at one end with a tapered shank and at its other end with a reduced screw-threaded part *A*, between the central helically threaded lead point *B* and the remaining



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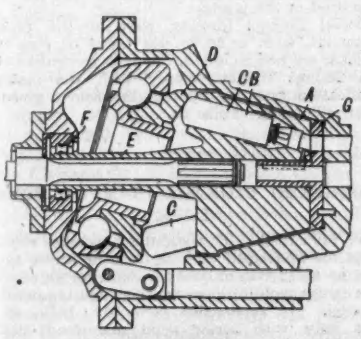
length of the spindle. A shoulder *C* is formed on the spindle at the rear of the screw-threaded part. The cutter-head *D* is provided with the diametrically opposed scriber *E* and chisel-edge or router *F*, the chisel edge or router forming one wall of an oblique open-ended slot *G* in the cutter head for the escape of cuttings removed by the chisel edge. Alternative constructions are also shown in the specification. As will be seen, the cutter-head can readily be moved from the spindle and replaced by another of different diameter for boring a different size of hole.—*June* 18, 1952.

PUMPS

673,746. March 3, 1949.—SWASH PLATE PUMPS OR MOTORS, Joseph Lucas, Ltd., of Great King Street, Birmingham, 10. (*Inventor: Thomas Alfred Harris.*)

The object of this invention is to enable the discharge end of the rotary body to be lubricated in a more satisfactory way than before. Referring to the drawing, the rotary body of the pump *A* is of truncated conical form, with inclined bores *B* for the plungers *C*. The swash plate *D* is at the larger end of the body *A*, and from this end there extends an integral hollow spindle *E*, which is supported in a bearing *F* in the housing. The smaller or discharge end of the rotary body co-operates with a stationary



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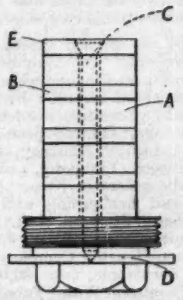
valve plate *G* with ports which successively establish communication between the bores and the liquid inlet and outlet passages. Secured to this valve plate is a short spindle, which enters a bore in the rotary body and serves to support the end of that body. In the body are formed passages extending from the plunger bores to the axial bore, which enables the liquid being pumped—for example, oil—to pass from the plunger bores under pressure to the spindle for its lubrication. A curved groove is also formed on the spindle to contain a film of the oil supplied. In an alternative design shown in the specification the spindle is formed and secured so that it is supported by the valve plate. In this case a passage between the outlet port of the pump and the bore in the valve plate for purposes of lubrication is provided.—*June* 11, 1952.

MISCELLANEOUS

673,699. September 20, 1949.—MAGNETIC CLEANERS, The Birmingham Small Arms Company, Ltd., Armoury Road, Small Heath, Birmingham; Donald Arthur Oliver, of the company's address; and Dennis Hadfield, 24, Delph House Road, Crosspool, Sheffield, 10.

The accompanying drawing shows a magnetic cleaner plug built in accordance with the invention. The plug comprises circular magnets *A* separated by thin brass members *B*. The assembly of magnets and brass separators is held together by a screw *C*, which is preferably of non-magnetic material, and



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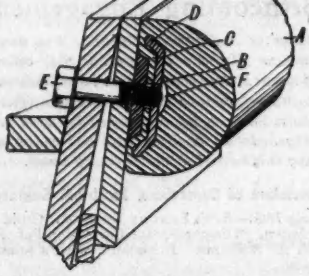
screws into a hole formed in the inner end of the screwed plug *D*. The purpose of the screwed plug is to secure the assembly in the crankcase. The uppermost layer of the assembly *E* is made of non-magnetic material. Although the magnetic layers are referred to as magnets, it will be appreciated that they are not necessarily magnetised before assembly. It is, in fact, preferable that magnetisation should be carried out after the assembly has been made.—*June* 11, 1952.

673,754. May 18, 1949.—RUBBER FENDERS OR BUFFERS, The Avon India Rubber Company, Ltd., and James Vallance Minto, both of Melksham, Wiltshire.

The invention relates to improvement in the fixture of fendering to objects requiring protection from damage, such as yachts, launches, dinghies, rafts, and the like. The fender component *A* is D-shaped in cross section, having a T-shaped slot *B* in the flat side, thus producing two flaps *C*. The



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slot receives a metal bar *D* which fits in the crossbar of the T-shaped slot. The hull of the vessel has holes drilled at regular intervals along its length for fixing screws *E*. The metal bar *D* need not be continuous, but in the form of separate elements of relatively short length, and this modification is shown in the specification. An inflatable chamber can be embodied in the resilient component in place of the air space.—*June* 11, 1952.

METALLURGY

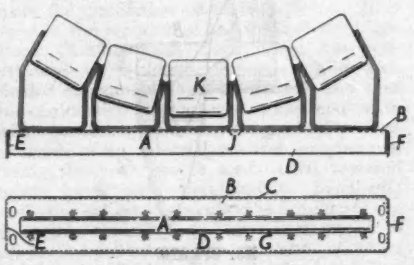
674,219. April 19, 1950.—HARD ALLOYS, Metro-Cutanit, Ltd., 160, Piccadilly, London, W.1.

This invention relates to a hard alloy suitable for use in the manufacture of cutting tools which can be operated at relatively low cutting speeds. According to the invention, a sintered hard alloy is made from tungsten carbide, titanium carbide and an auxiliary metal, and contains 2–7 per cent titanium carbide, 16–21 per cent, preferably 16–18 per cent, auxiliary metal, such as iron, cobalt or nickel and the remainder tungsten carbide. It has been found to be of advantage to add to the alloy of this invention up to 2 per cent of chromium or chromium carbide. Also an addition of comparatively soft carbides, i.e., those of tantalum, columbium, molybdenum, vanadium or zirconium, in amounts of up to a total of 10 per cent may be provided. In this case very tough and wear-resistant hard alloys are obtained. The field of employment of these new alloys lies in cutting speeds which amount to 80–250 per cent of the speed which is possible with high-speed steel.—*June* 18, 1952.

CONVEYORS AND TRANSPORTERS

674,269. January 16, 1950.—BELT CONVEYORS, Babcock and Wilcox, Ltd., Babcock House, Farringdon Street, London, E.C.4. (*Inventor: John Henry Ratzer.*)

An object of the invention is the provision of improved supporting means for the idler rollers of belt conveyors. The transom *A* illustrated in the drawing has a length slightly greater than 3ft 6in and is pressed from No. 9 gauge mild steel sheet. The transom includes a top or platform *B* having, at opposite sides, rearwardly extending flanges *C* and *D* and, at its ends, rearwardly extending flanges *E* and *F*. The platform is formed with a single



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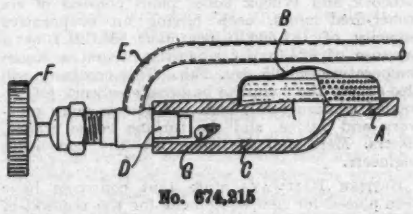
central, continuous upstanding rib *G*, having a width somewhat less than a third of the platform, and raised above the surface of the platform by a distance approximately equal to the thickness of the sheet metal of which the transom is formed. The brackets *J*, supporting the rollers *K*, are bolted to the transom. The brackets are pressed from No. 7 gauge steel and each is formed with a central rib extending along the base and arms to fit the platform rib. The bracket is formed with vertical arms inclined to locate the outer troughing rollers in appropriate positions. The arms of each bracket exert a spring action for holding the spindle of the roller.—*June* 18, 1952.

BURNERS AND SPRAYERS

674,215. April 3, 1950.—OIL BURNERS, Aktiebolaget Famulus, Bredgrand 2, Stockholm, Sweden.

In vaporised fuel burners burning cheap fuels the flame has a tendency to burn irregularly, to smoke or go out, and the range of flame control is very limited. The object of the invention is to obviate these inconveniences by arranging the air inlets in a particular manner in the mixing tube piece. As shown in the drawing, a cup-shaped distributing plate *A* covered by a flame shaping hood *B* is integral with a hollow burner mixing tube *C* in which a fuel supply nozzle *D* is inserted. The fuel



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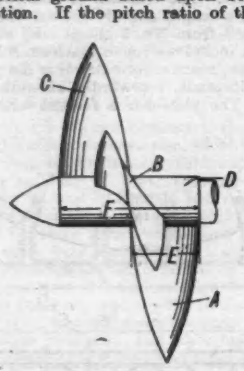
is supplied through a conduit *E* and the supply is controlled by turning a knurled knob *F*. Provided in the mixing tube *C* are two air inlets *G*. More than two inlets may be used, but it is important that all

of the inlets should be located in the lower half of the side wall of the mixing tube and shaped relatively to the direction of flow of the fuel. According to the design shown, the inlets are so shaped that the air streams encounter the fuel stream at an angle of approximately 30 deg., but small departures from this angle may occur. The flame-shaping hood has an annular edge in which gas discharge openings are distributed in parallel rows. In practice, thin arrangement of the air inlets and the gas discharge openings have been found to be very advantageous and suitable also in connection with the use of cheap types of fuel.—*June* 18, 1952.

MARINE ENGINEERING

674,216. April 4, 1950.—SCREW PROPELLERS WITH MULTIPLE BLADES, Hidetsugu Kubota, 1122, Kizuka, Kamedamachi, Nakakambara-gun, Niigata-ken, Japan.

This invention relates to an axial screw propeller with multiple blades disposed at an equal distance apart both axially as well as angularly, which is claimed to be a highly efficient design suitable for high-speed rotation. Referring to the drawings, it will be seen that the propeller is provided with three blades, the foremost blade *A*, intermediate blade *B*, and rearmost blade *C*, each having a different blade surface. The pitch of the propeller is deduced from the theoretical ground based upon both the slip and induction. If the pitch ratio of the foremost



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blade *A* is selected to be 1·0, the pitch ratio of the intermediate blade *B* will become 1·0 plus slip 0·2—that is 1·2. With respect to the rearmost blade *C*, the pitch ratio of this should be chosen at 1·2, because it is free from the action of induction 0·2. The arrangement of three blade roots in a length *F* corresponding to twice the root length *E* of each blade is shown in the drawing. Experimental tank curves for the propeller are given in the specification.—*June* 18, 1952.

Contracts

THE GENERAL ELECTRIC COMPANY, Ltd., has received a contract for a complete iron ore handling plant to the value of over £1 million for Invest Import, Belgrade. The plant, which is to have a capacity of 500–690 tons per hour, includes mechanical and electrical equipment and will be manufactured at the Fraser and Chalmers engineering works and the Witton engineering works of the G.E.C. Delivery to the Zenica Iron Works, Yugoslavia, is scheduled for two years. This installation will form part of a complete ironmaking plant, the consultants for which are Meckenzie Engineering, Ltd., of London.

BABCOCK AND WILCOX, Ltd., and THE GENERAL ELECTRIC COMPANY, Ltd., have received orders for £4,000,000 worth of boiler and generating plant, to be installed in the new Kelvin power station, some 10 miles north-east of the city of Johannesburg. Three 30MW, 11kV, 3000 r.p.m. alternators will be built in the electrical engineering works of the G.E.C. at Witton and the turbines at Fraser and Chalmers Engineering Works, Erith, Kent. The Babcock and Wilcox boiler plant consists of six stoker-fired units, each having an evaporative capacity of 187,500 lb per hour (M.C.R.) at a pressure of 625 lb per square inch and a steam temperature of 865 deg. Fah. This company will also supply the complete building steelwork (of all-welded construction), high and low-pressure pipework and valves, and the turbine house cranes. Messrs. Merz and McLellan are the consulting engineers.

BRITISH RAILWAYS state that contracts have been placed for new equipment for the renewal of the Southern Region's power supply system for the electrified lines at a cost of about £12 million. Current for the existing system, parts of which date back to 1915, is supplied at 25 c/s from the Southern Region power-house at Durnsford Road, Wimbledon, and through the B.E.A. station at Deptford. The new system will operate at the national standard frequency of 50 c/s and will take current from the Deptford station, which is being rebuilt, and direct from the national grid. The Durnsford Road station equipment, now nearing the end of its life, is not to be renewed. The principal contracts placed in connection with the new scheme are :—High-voltage switchgear, The General Electric Company, Ltd., and The British Thomson-Houston Company, Ltd.; rectifier equipment, Hackbridge and Hewittic Electric Company, Ltd., The General Electric Company, Ltd., and The English Electric Company, Ltd.; d.c. switchgear, The British Thomson-Houston Company, Ltd., and Bertram Thomas, Engineers, Ltd.; high-voltage and pilot cables, Pirelli-General Cable Works, Ltd. The new system will enable ten-car electric trains to be introduced on the congested Eastern Section suburban lines, instead of eight-car trains, as at present, and the first stage, which, it is hoped to bring into operation in 1954, provides for ten-car trains running on the routes between Charing Cross and Dartford via Bexleyheath, and between Charing Cross and Orpington. To accommodate the longer trains platforms of stations on the routes will be extended and the layout of certain of the tracks between Charing Cross and London Bridge replanned at an additional cost of over £½ million.

DURING June the British Electricity Authority has placed contracts for equipment for power stations amounting in the aggregate to £9,290,000. The principal contracts include : Brunswick Wharf, one 60MW turbo-generator, condensing and feed heating plants, &c. (Metropolitan-Vickers Electrical Company, Ltd.); Hackney, 6·6kV switchgear (General Electric Company, Ltd.); Woolwich, one 30MW turbo-generator (General Electric Company, Ltd.), and condensing and feed heating plant (Worthington-Simpson, Ltd.); Marchwood, near Southampton, two 60MW turbo-generators (British Thomson-Houston Company, Ltd.); East Yelland, near Barnstaple, two 180,000 lb per hour boilers (John Thompson Water Tube Boilers, Ltd.); Goldington, Bedford, structural steelwork (J. Booth and Sons (Bolton), Ltd.), two 300,000 lb per hour boilers (Clarke Chapman and Co., Ltd.), two 30MW turbo-generators (British Thomson-Houston Company, Ltd.), and condensing and feed heating plants (G. and J. Weir, Ltd.); Brimsdown, near Enfield, foundation and building works for third extension (Walter Lawrence and Son, Ltd); Hams Hall "C," Birmingham, three 60MW turbo-generators (General Electric Company, Ltd.); Ince, near Ellesmere Port, one 60MW turbo-generator (General Electric Company, Ltd.), and condensing and feed heating plant (Hick, Hargreaves and Co., Ltd.); Blackburn, building and iron store and workshops (Holst and Co., Ltd.); Rotherham, high-pressure pipework (Stewarts and Lloyds, Ltd.); Keadby, near Scunthorpe, two 550,000 lb per hour boilers (Stirling Boiler Company); Stella North, near Newcastle upon Tyne, coal handling plant (Birtley and Co., Ltd.); Stella South, low-pressure piping equipment (Aiton and Co., Ltd.), and Huncoat, Accrington, two 30MW turbo-generators and generator transformers (General Electric Company, Ltd.), and main auxiliary and control cables and connections (W. T. Glover and Co., Ltd.).

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Supervising Electrical Engineers

Wed., July 16th.—S.W. LONDON BRANCH: Guild House, Wimbledon. "Power Factor Correction," J. Fletcher and T. A. Williams. Illustrated with a sound film, 7.15 p.m.

Institution of Civil Engineers

To-day, July 11th.—Summer meeting in Coventry and Stratford-upon-Avon. Coaches leave the James Watt Memorial Institute, Great Charles Street, Birmingham, 1 p.m.

Institution of Electrical Engineers

Wed., July 16th.—N.E. STUDENT'S SECTION: Visit to the Hebburn Works of Pyrotenax Ltd., 6.30 p.m.

Manchester Association of Engineers

Sat., July 19th.—Visit to Messrs. Cammell Laird's Shipyards, Birkenhead, 2 p.m.

Old Centralians

Mon., July 14th.—Chez Auguste Restaurant, 47, Frith Street, London, W.1. "World Oil Reserves," G. M. Lees, 12.55 p.m.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

BITUMINOUS-BASE FILLING COMPOUNDS FOR ELECTRICAL PURPOSES

No. 1858 : 1952. This standard supersedes B.S. 688 and B.S. 803, which are now withdrawn, and applies to bituminous compounds which may be subjected to electrical stresses in service, either in electrical apparatus or in cable boxes. It does not, however, cover oils and oil-resisting compounds. The compounds dealt with are classified according to their softening points; electrical and physical properties are specified and full details are given of the tests required to determine these properties. These tests are based as far as possible upon those described in the *Standard Methods of Testing Petroleum and its Products*, as issued by the Institute of Petroleum. The two earlier standards were prepared at different times to cover respectively bituminous compounds for electrical apparatus and those for cable boxes up to 11kV. The main differences between them and the new standard are that the minimum permissible values of penetration have been reduced, the tolerance in the softening points has been slightly increased, while the acidity test is now optional and the test for resistance to moisture has been omitted. Price 6s.

SOLID DRAWN COPPER-SILICON TUBES FOR GENERAL PURPOSES

No. 1866 : 1952. This standard sets out the preferred method of designating tubes of ¼in up to and including 6in outside diameter, and specifies the permitted tolerances on diameter, thickness, and length for tubes within this range. It gives the chemical composition and mechanical properties and includes details of making the mechanical tests and a mercurous nitrate test. Tolerances on width, length and thickness are tabulated. Price 2s.

MILK PIPING AND MILK PIPE FITTINGS

No. 1864 : 1952. This standard covers milk pipes of stainless steel and tinned copper, together with milk pipe fittings of stainless steel, tinned bronze and tinned gunmetal. After full consideration of the alternatives the compressible ring joint design has been adopted. The dimensional standards permit the use of both stainless steel and tinned copper in the same installation, but it has not been possible to arrange permissible tolerances to ensure that a tinned gunmetal fitting will fit any sample of stainless steel pipe without slight enlargement of the recess bore. It has not been possible to include any device to restrict the movement of the nut along a length of pipe when uncoupled. The necessity for this can, however, be avoided to some extent by fitting pipes with male parts whenever possible. This British Standard covers the following five nominal outside diameters, 1in, 1¼in, 2in, 2½in, and 3in. For pipes it specifies details of material, dimensions and tolerances, manufacture and finish. For the fittings it specifies details of the material, dimensions and tolerances, ring joints, finish, threads and includes details or symbols to indicate various joints, unions, bends, &c. Tables are included giving exact dimensions for the various parts, together with the necessary tolerances. Appendices include a specification for rubber rings to be used in the joints.

Special fittings forming part of the process equipment, such as cocks for tanks or pipe connections, are not included, but it is recognised that such fittings should comply with the material specification and the leading dimensions given in the specification. Price 5s.

UNDERFEED STOKERS (RAM OR SCREW TYPE)

No. 749 : 1952. This standard specifies requirements for underfeed stokers (ram or screw type), rated up to 1200 lb of coal per hour, for all applications except metallurgical or other high-temperature furnaces. It supersedes B.S. 749 : 1937, which dealt only with screw type underfeed stokers primarily intended for use in conjunction with domestic and central heating boilers of the sectional type. For the guidance of users, appendices are included giving general recommendations on installation and maintenance, including the application of automatic control, for which stokers of the underfeed type are particularly suitable, rating by heat output, and suitable fuels. Price 3s.